SEDIMENT TOXICITY IDENTIFICATION EVALUATION DEMONSTRATION: INDIAN HEAD NAVAL SURFACE WARFARE CENTER

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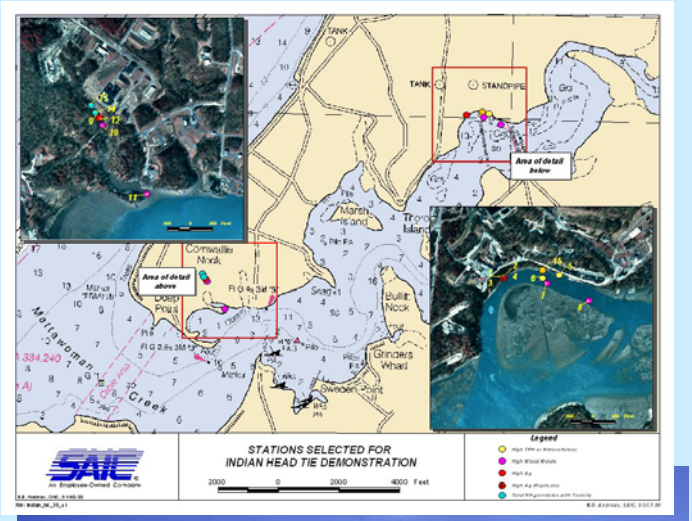

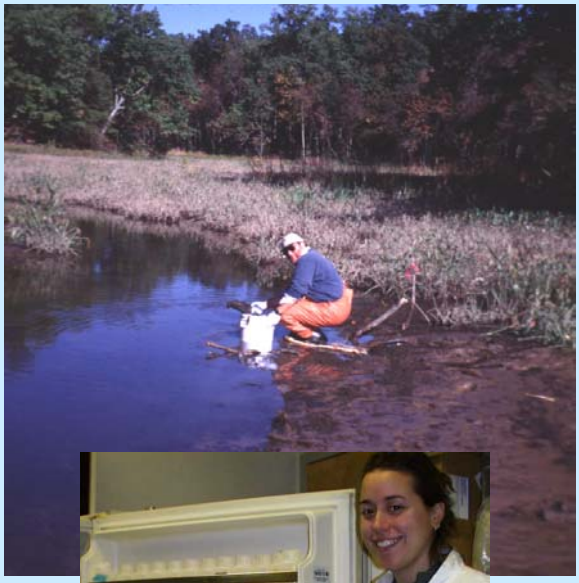

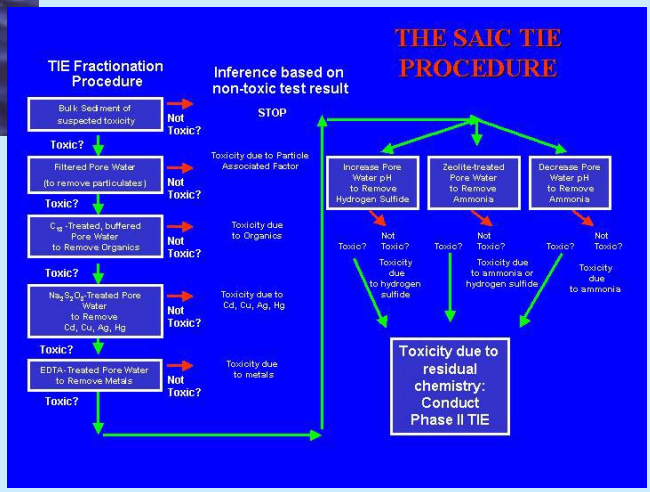

SUBMITTED TO:

DEPARTMENT OF THE NAVY

NAVAL FACILITIES ENGINEERING SERVICE CENTER

Contract No. N47408-00-C-7123

Final Report - October 2001

SITE REPORT FOR:

SEDIMENT TOXICITY IDENTIFICATION EVALUATION DEMONSTRATION:

INDIAN HEAD
NAVAL SURFACE WARFARE CENTER

SUBMITTED TO:

DEPARTMENT OF THE NAVY
NAVAL FACILITIES ENGINEERING SERVICE CENTER
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IN RESPONSE TO:

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EXECUTIVE SUMMARY

A Toxicity Identification Evaluation (TIE) demonstration was conducted using sediment pore waters from the Naval Surface Warfare Center (NSWC) at Indian Head, MD. The study was part of a demonstration project for Naval Facilities (NAVFAC) (technically managed by U.S. Navy Engineering Field Activity Northeast (EFANE)) designed to illustrate the applicability of TIEs in resolving regulatory uncertainties associated with management of contaminated sediments.

Fifteen sediment samples were collected for the study on 12 October, 2000 from two areas at the Indian Head Naval Base: six from the Olsen Landfill Site (Area 42) and eight from the Mattawoman Creek and beach area adjacent to an organics plant and scrap yard (Area 39/41). Additional sediment was collected from a station upstream from Area 39/41, near 'Slavin's dock', where contamination from a burn site was visible. Following bulk sediment tests with a freshwater amphipod (*Hyalella azteca)* to screen out any non-toxic sediments, ten pore waters were chosen from the fifteen sediment samples. The subset consisted of samples that were expected to have a variety of contaminant types and/or ammonia in toxic concentrations. The samples were also selected to address issues concerning spatial variability.

The TIE consisted of a sequential series of toxicity tests consisting of exposures to serial dilutions of pore waters using *Hyalella* and larvae of the fathead minnow *(Pimephales promelas)*. These are species that are commonly used to represent toxicity of sediments and effluents. Members of each species were exposed to untreated sediment pore waters, and then to a series of treated pore waters resulting from five sequential steps and two additional individual manipulation steps designed to alter toxicity of specific contaminant groups. These were:

Filtration: Removes excess particulates to improve efficiency of subsequent treatments.
C_{18} column extraction: Removes non-polar organic contaminants such as polynuclear aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs).
Sodium thiosulfate ($Na_2S_2O_3$): Reduces oxidants such as chlorine, dichloramines and some of the cationic metals (Cd^{2+}, Cu^{2+}, Ag^{1+}, and Hg^{2+}).
Ethylenediamine Tetraacetic Acid (EDTA): Chelates divalent cationic metals (i.e., Al^{2+}, Ba^{2+}, Fe^{2+}, Mn^{2+}, Sr^{2+}, Cu^{2+}, Ni^{2+}, Pb^{2+}, Cd^{2+}, Co^{2+}, and Zn^{2+}), replacing dissolved metals with less bioavailable forms.
Zeolite: Removes ammonia.

Following EDTA chelation, the following pH adjustments are performed to clarify the role of confounding factors associated with reduced toxicity in the zeolite treatment:
Decrease pH; Change the equilibrium of ammonia to favor the less toxic ionized form (NH_4^+); change the equilibrium of sulfides to favor the more toxic, hydrogen sulfide form.
Increase pH; Change the equilibrium of ammonia to favor the more toxic unionized form; change the equilibrium of sulfides to favor less toxic forms.

Samples were collected in two primary areas (Site 42 and Site 39/41) in order to capture a variety of contaminants and exposure conditions. Samples collected at Site 42 were focused on silver as the potential source of toxicity. All 15 of the stations were toxic to *Hyalella* in bulk sediments. There was considerable variability in TIE responses and in chemical measurements amongst the fifteen sampled sediments. The following are principal findings of the TIE study.

- The extent of toxicity observed in pore water was generally less than that observed in the bulk sediment; only 6 of 10 samples exhibited toxicity in pore water exposures to *Hyalella* and *Pimephales*. Responses of the two species to the various TIE treatments were in generally good agreement.
- Sample filtration resulted in partial toxicity removal at Stations 6 and 11, suggesting toxicity associated with the particulate fraction of the sample.
- C_{18} treatment for organics removal generally did not result in decreased toxicity, indicating PAHs, PCBs and non-polar pesticides were not responsible for the observed toxicity.
- Sodium thiosulfate additions that would bind certain metals including silver did not appear to moderate observed toxicity at Site 42 stations. Therefore, it is unlikely that silver contributed significantly to toxic effects in pore water. Toxicity reduction was observed at one Area 39/41 location (Station 2), and matching chemical data support a potential role of silver toxicity in this sample.
- EDTA chelations to remove the remaining metals showed response in three samples (Stations 6, 11 and 15). Reductions in toxicity at Stations 6 and 11 are consistent with toxicity associated with high pore water manganese. Station 15 TIE and chemistry results are consistent with toxicity associated with zinc.
- Zeolite and associated pH adjustment implicated ammonia as a principal source of toxicity in at least one location (Station 8), and as a partial source of toxicity at Station 2.
- The TIE treatments successfully removed toxicity in all but one location (Station 2). Toxicity at this location is possibly confounded by residual toxicity from polar pesticides (beta-BHC), water hardness, exotics (explosives), and unusual organic carbon ratios in the pore water. To determine whether the toxicity is associated with pesticides will require a Phase II TIE incorporating an elution column that specifically targets organochlorine pesticides.

In general, there was good agreement between sediment and pore water test results. However, four stations were found to be toxic in bulk sediment but not in pore water. This may be because the sediment and water tests represent different exposure durations (10 vs. 3 days, respectively), or that the TIE did not represent all potentially meaningful sources of ecological stress to aquatic organism. Other factors may include sediment lithological incompatibility for the test organisms and higher sulfide in bulk sediment that was not carried forward into the pore water exposures.

1. INTRODUCTION

The Naval Surface Warfare Center at Indian Head, Maryland, a location with tidal fresh, potentially contaminant-impacted aquatic habitats, was chosen as one of two sites to be evaluated as part of the Sediment Toxicity Identification Evaluation (TIE) demonstration project for NAVFAC. The Technical Proposal for the Demonstration Project was submitted and approved in March 2000 (SAIC 2000a). Indian Head was chosen as a demonstration site because it conforms to the principal site-selection criteria developed for the project designed to resolve ecological risk concerns:

- An identified need exists for information that may clarify the source of apparent toxicity in creek sediments adjacent to Site 42 (Olson Road Landfill). Thus, results from the TIE should help to resolve uncertainties and support site management decisions.

- The study site presents a unique case study in relation to environmental and contaminant characteristics relative to the other chosen site. Thus, the TIE program should demonstrate applicability in diverse habitat conditions, and serve to address uncertainties with regard to the principal toxic agents that may be found across a wide variety of Navy sites.

The Program Team involved in addressing remediation at the site includes the primary technical team (SAIC), the oversight/liaison team (U.S. Navy Engineering Field Activity Northeast/Navy Facilities Engineering Service Center [EFANE/NFESC]), the Installation Restoration support team (EFAChes IR staff and contractors), the Activity Team (Indian Head NSWC staff) and the Regulatory Team (Region III Biological Technical Assistance Group (BTAG)). The Program Team was committed to a close collaboration with the TIE effort to assure successful and efficient study designs and sampling efforts.

1.1. BACKGROUND

Sufficient data were presented in a Remedial Investigation report (Tetra Tech NUS 1999a) to propose that two locations at Indian Head were appropriate for the TIE Demonstration: Site 42, known as the Olsen Road Landfill, and Site 39/41 where an Organics Plant and Scrap Yard are located. The principal identified Contaminant of Potential Concern (CoPC) was silver.

A remedial excavation to remove silver-contaminated soils from two swales that drained into Site 42 was completed in 1994 and resulted in reductions to below the 10 mg/kg action level for silver (a value that marks the concentration distribution for 99% of sediments in the National Sediment Inventory; U.S. EPA 1997). However, silver was measured at concentrations above the action level in Site 42 sediments, and was identified by the BTAG as the CoPC for aquatic receptors at this site. Subsequently, bulk sediment toxicity tests were conducted on Site 42 samples, and toxicity was demonstrated in each of thirteen representative sediments (Tetra Tech NUS 1999b). Hence, ammonia was implicated as a confounding factor contributing to observed toxicity (Tetra Tech NUS 1999b) and other contaminants have not been conclusively excluded as contributors to toxicity (Tetra Tech NUS 1999a).

The Remedial Investigation also found silver concentrations at Sites 39/41 in the same range or higher than in Site 42, along with some additional CoPCs that were not identified for Site 42. This was consistent with data from surveys conducted in 1992 and 1997 that indicated that mercury, nickel and nitrocellulose were included as potentials risk contributors. These analytes were also CoPCs for Site 39/41 (Tetra Tech NUS 1999a).

1.2. OBJECTIVES

The objectives of the proposed Phase 1 TIE study are to provide data to identify sources and magnitude of toxicity associated with contaminants at the site as well as to characterize the extent to which confounding factors (e.g., ammonia) are potentially involved in the toxic response. The sampling design developed to meet these objectives as well as a review of the technical approaches and methodologies used for field and laboratory analysis is discussed in Section 2. Results and conclusions are presented in Sections 3 and 4, respectively, with references provided in Section 5.

2. TECHNICAL APPROACH

The choice of sampling locations within Site 42 and additional samples at Area 39/41 in Mattawoman Creek are shown in Figure 2.0-1. Some of these locations were specifically chosen based on evaluation of prior data for purposes of assessing the potential contribution of silver relative to other sources of toxicity to aquatic receptors at the Indian Head sites (SAIC 2000a). Other stations have also been chosen to maximize opportunities to observe and characterize potential toxicity from silver, other CoPC and confounding factors, and to provide a representation of the varying contaminant signatures and sediment characteristics that occur across Site 39/41 and Site 42.

In the following Sections, the technical approach for interpretation of the chemistry data (Section 2.1) and TIE data (Section 2.2) is discussed with particular emphasis on the likelihood of silver toxicity versus other factors for locations at Site 42. Field and laboratory methodologies (Section 2.3) and statistical analyses (Section 2.4) are also presented.

2.1. RATIONALE FOR CHEMICAL EVALUATION

Aspects of the toxicology of silver and other identified chemicals at the Indian Head Sites 42 and 39/41 with respect to the potential for toxicity is discussed in this section. For purposes of the TIE Demonstration, the chemistry data from each of the selected stations were assessed for toxicity potential based on one or more of the following characteristics:

- Bulk sediment concentrations that exceed benchmarks for potential/probable effects (Section 2.1.1);
- Divalent metal concentrations (simultaneously extracted metal (SEM)) that enhance potential for divalent metal (Cu, Cd, Pb, Ni, Zn) and silver (Ag) toxicity (Section 2.1.2);

- Pore water benchmark exceedences that will reflect location-specific sediment characteristics (e.g., total organic carbon (TOC) that govern chemical bioavailability (Section 2.1.3);
- Non-CoC sources (e.g., NH_4) that confound the elucidation of CoC contributions to toxicity (Section 2.1.4);
- Contaminants other than the identified CoCs (e.g., total petroleum hydrocarbons, nitrocellulose) that are observed at elevated concentrations and hence may contribute to toxicity (Section 2.1.5); and
- Spatial variation that might reflect novel environmental conditions or CoPC distributions that may represent gradients in chemical availability (Section 2.1.6).

2.1.1. Sediment Benchmark Exceedences.

Results of the bulk sediment analyses were compared to selected sediment benchmarks to reflect the potential for toxicity of the sample. The sediment-based benchmarks used to evaluate the exposure conditions of concern at Indian Head Sites 39/41 and 42 are from U.S. EPA (1997) and NOAA (1997) and are summarized in Table 2.1-1. Most values are NOAA Probable Effect Levels (PELs) and Upper Effect Threshold (UET) concentrations. When such values were not available, alternate freshwater and then marine benchmarks for probable effects (e.g., PELs) were generally used. For silver, the selected benchmark value (4.5 µg/kg dry weight) is based on the UET concentration observed for the *Hyalella azteca* bioassay (NOAA 1998). This benchmark is relevant to the Indian Head site as it is based on a freshwater species that can be expected to occur in the region. It is the only published benchmark for silver in freshwater sediments, however, and thus it is not possible to compare the degree of protectiveness that this benchmark affords.

It is noted that the above sediment contaminant benchmarks are derived from field measurements of adverse effects expressed in a variety of ways (e.g., toxicity, decreased benthic diversity) and hence frequently reflect the cumulative response to the co-occurrence of multiple contaminants. Often these co-contaminants are at very elevated levels, and most of the data has originated from highly contaminated sites. Accordingly, the resulting chemical-specific benchmarks can be overly conservative. With these uncertainties in mind, it is important to evaluate other measures of potential toxicity, as discussed in the following sections.

2.1.2. Divalent Metals Bioavailability.

Simultaneously Extractable Metal:Acid Volatile Sulfide (SEM:AVS) measurements are conducted on sediments to assess the bioavailability and hence toxicity of divalent metals. In this method, the amount of metal liberated form the sample during extraction is measured, and at the same time, the quantity if sulfide released from the sediment is also measured. Sulfides are a common constituent of organic-rich sediments that will bind divalent metals in direct proportion to their respective molar concentrations (Hansen *et al*. 1996). As for the bioavailability of the monovalent metal, Silver, Berry *et al*. (1999) has demonstrated that this metal responds like other SEM metals in binding to AVS when the metal occurs in excess of the available AVS concentration (Ag/2-AVS), toxicity can be accurately predicted. Hence, for Indian Head, SEM:AVS data incorporating silver was used to select locations and evaluate the potential for silver and other divalent metal toxicity.

The difference approach (SEM-AVS) for quantifying SEM:AVS data was used in the present evaluation as it most accurately represents available SEM concentrations; the more traditional ratio approach (SEM/AVS) commonly used tends to misrepresent available concentrations of SEM at low AVS concentrations. The EPA National Sediment Quality Inventory has adopted the difference approach; an SEM-AVS value of 5 µM/g dry wt is recommended as a screening value for identification of bedded sediments of concern with regard to potential divalent metal effects on aquatic biota (U.S. EPA 1997).

In planning the Indian Head TIE study, estimated as well as measured SEM:AVS data were used to identify locations of potential metal toxicity for the purposes of station selection for the TIE demonstration (SAIC 2000a). Until recently SEM:AVS analyses were not typically included in sediment chemistry measurements, hence the evaluation of historical sediment data for potential divalent metals toxicity is problematic. Here, the concentration of SEM can be roughly estimated to be equal to the corresponding bulk sediment concentration due to similarity in the chemical extraction methods for SEM and typical bulk sediment metals analysis (both are weak acid digestion methods). Also, in the absence of AVS data, iron concentration in bulk sediment may be used as an indicator of AVS binding capacity. This is because the principal form of AVS is iron monosulfide (FeS), although the more stable pyrite form (FeS_2) might also be present. While this approach was used in the station selection process, direct measurements of SEM:AVS were employed in the TIE investigation.

2.1.3. Pore Water Benchmark Exceedences.

Similar to the bulk sediment benchmark comparisons, pore water chemistry data are used for comparison with water quality benchmarks to assess the potential for toxicity of the sample. For metals of concern in the current study, the appropriate pore water benchmarks are the USEPA Water Quality Criteria - Freshwater Acute (WQC-FA) values (Table 2.1-2). In contrast to metals, pore water benchmarks for organics were derived from sediment benchmarks using the Equilibrium Partitioning (EqP) model approach of DiToro *et al.* (1992) as follows:

$$1) \qquad C_p = C_s/(f_{oc} * K_{oc})$$

In the above equation, organic chemical pore water concentrations (C_p, µg/L) are calculated from the corresponding sediment concentration (C_s; µg/kg) based on the fraction of organic carbon (f_{oc}) in the site sediment (f_{oc} = %TOC/100) and the organic carbon/water partitioning coefficient (K_{oc}) for the CoPC. Values for K_{oc} are determined from the relationship developed by the USEPA (Karickhoff *et al.* 1989):

$$2) \qquad \log_{10}K_{oc} = 0.00028 + 0.983*\log_{10}K_{ow}$$

where K_{ow} = the octanol/water partition coefficient. In this process, it is assumed that the resultant value provides a level of protection equivalent to other water quality based benchmarks. For purposes of completing the benchmark table for organics (Table 2.1-2), the sediment benchmark values were transformed into water-equivalent benchmarks using the EqP model by assuming a default value of 1%

sediment TOC concentration. However, when the sediment-based benchmarks were applied to the site sediment, the benchmark was adjusted based on the measured TOC in sample. It is noted that these estimated benchmarks tend to be overly conservative, as in many cases they are several orders of magnitude lower than published WQC benchmarks (based on lowest observed effect level) when both are available for comparison.

In the present TIE study, concentrations of chemicals measured directly in pore water (i.e. metals) or for organics, predicted using the EqP model described above (i.e. organics), were subsequently compared to the pore water benchmarks to calculate Hazard Quotients (HQs). These HQs were used to assess the potential for pore water chemicals to cause toxicity.

2.1.4. Non-CoPC Toxicity Sources.

In the present study, locations of varying ammonia and hydrogen sulfide in sediment were selected to examine these potential sources of non-CoPC toxicity. In the historical and recent surveys conducted at the Indian Head site, only a limited number of samples were analyzed for these parameters. Hence, the potential for direct effects of these common non-CoPC constituents of sediments is largely unknown.

Ammonia. Ammonia is a well-known source of potential toxicity in aquatic sediments. In a TIE evaluation conducted with sediment pore waters from the Blackstone River, MA, thresholds for *Hyalella* survival were 25 mg/L total ammonia but only 0.5 mg/L un-ionized ammonia (SAIC 2000b). These values compare well with No Observable Effect Concentrations (NOECs) generally observed for saltwater species (30-60 mg/L total ammonia, 0.4-0.8 mg/L NH_4; U.S. EPA 1994).

Available ammonia data from the previous laboratory tests of bulk sediment from the site were well below concentrations associated with toxicity to *Hyalell*a. However, an interpretation that ammonia was not a source of toxicity is uncertain because measurements were only made on over-lying water and an important co-factor, pH, that modifies ammonia toxicity was not quantified. The importance of incorporating pH into the toxicity assessment is underscored by the fact that the new National Criteria for Ammonia in Fresh Water (U.S. EPA 1999) recommends the site-specific calculation or the freshwater acute value (WQC-FA) as the pH-dependent, un-ionized form (NH_4) rather than as a single unionized ammonia value, as follows:

$$\text{WQC-FA} = [0.275/(1 + 10^{7.204-\text{pH}})] + [39.0//(1 + 10^{\text{pH}-7.204})]$$

Accordingly, the algorithm presented above was used to generate the benchmark for ammonia toxicity for each location at Indian Head.

Hydrogen sulfide. Hydrogen sulfide is another potential contributor to toxicity in pore waters that is often overlooked. In a review focusing on sediment toxicity, Wang and Chapman (1999) provide a comprehensive summary of the available data concerning sulfide toxicity to benthic invertebrates and report 96 hr acute LC_{50} values ranging from 0.02-1.1 mg total sulfide/L. Specific data for the organisms

used in the present study were not included. Hence, these values were qualitatively used to assess potential sulfide toxicity in the present study.

2.1.5. Contaminants other than CoPCs.

A limited number of additional organic contaminants that are found in Indian Head sediments have uncertain threshold concentrations for effects (SAIC 2000a), including Total Petroleum Hydrocarbons (TPH) and nitrocellulose. While TPH is often associated with equivalent concentrations of PAHs, the measurement actually reflects a broad mixture of constituents including PAHs, linear alkanes, and other compounds that may have little or no toxicity. For nitrocellulose, a compound associated with explosives, no published data are available regarding the potential acute effects of this chemical on aquatic organisms. It is also recognized that these chemical classes may fall outside the range of CoCs for which the TIE treatments were designed. Given the production of explosives at the site, the presence of nitrocellulose was viewed as a marker for a larger group of compounds that may represent a potential source of toxicity.

2.1.6. Spatial Heterogeneity in Sample Toxicity.

Characterizations of existing data at Sites 39/41 and Site 42 have demonstrated a high degree of variability, reflecting multiple sources of contamination and the potential presence of a range of factors that affect bioavailability and spatial variability. Accordingly, in the present TIE investigation, stations reflect locations with the greatest potential for toxicity but also to broadly assess the potential factors governing toxicity.

2.2. TIE TECHNICAL APPROACH

In a TIE investigation, the physical/chemical properties of sediment pore water samples are manipulated in order to alter or render biologically unavailable generic classes of chemicals (U.S. EPA 1991). Because contaminated sediments are often toxic to aquatic organisms, fractions exhibiting toxicity reveal the nature of the toxicant(s). Depending upon the responses, the toxicant(s) can be tentatively categorized as having chemical characteristics of non-polar organics, cationic metals or confounding factors such as ammonia (U.S. EPA 1996).

Procedures for conducting specific TIE steps developed by U.S. EPA (1996) describing specific methodologies and QA/QC procedures form the basis for the technical approach. SAIC has modified the EPA approach by applying sequential testing of fractions and to permit documentation of cumulative toxicity removal up to and including the production of completely non-toxic samples (Figure 2.2-1). This approach is preferred because absence of residual toxicity provides a clearer demonstration that all the relevant chemical exposures in a sample can be adequately accounted for. For example, at the Naval Submarine Base-New London, CT, prior remedial investigation and risk assessment studies for Goss Cove suggested actionable risk although considerable uncertainty existed as to the contaminants responsible for risk (Navy RPM News 1999; SAIC 1999). The application of the improved TIE

process revealed that ammonia (a ubiquitous non-CoPC sediment constituent) and not the suspected sediment contaminants (e.g., PAHs, metals) was responsible for the toxicity.

TIE Manipulations. The Phase I TIE characterization consists of the following characterization steps or tiers: (1a) Baseline Toxicity Test and (1b) Filtered Sample Toxicity, (2) C_{18} column extraction, (3) sodium thiosulfate ($Na_2S_2O_3$), (4) ethylenediamine tetraacetic acid (EDTA), (5) zeolite and (6) graduated pH. The pore waters were manipulated according to the sequential extraction scheme shown in Figure 2.2-1. Guidelines for TIE data interpretation are presented in U.S. EPA (1991) and are summarized below:

1a. **Untreated pore water toxicity**.

1b. **Filtration**: The pore water is filtered with 0.45µm filter paper to remove particulates. Toxicity tests conducted on the pre- and post-filtered fraction permit elucidation of potential toxicity associated with large colloids or particulates in the pore water.

2. **C_{18} column extraction**: Pore water samples are eluted through C_{18} exchange columns (Waters, Sep-Pak® Classic short-body type cartridge) to remove organic compounds and other metals that are relatively non-polar (U.S. EPA 1991). According to Waters' procedures, the pore water is treated at a rate of 10 ml/minute. For each pore water sample, the column is exchanged after one liter is eluted. A reduction in toxicity response to C_{18} treatment indicates the potential role of organic compounds as a contributor to the toxicity of pore waters.

3. **Sodium thiosulfate**: Sodium thiosulfate ($Na_2S_2O_3$) is used to reduce oxidants such as chlorine, ozone, chlorine dioxide, mono and dichloramines, bromine, iodine, manganous ions, and some electrophilic organic chemicals and to remove cationic metals including Cd^{2+}, Cu^{2+}, Ag^{1+}, and Hg^{2+} in the pore water samples (U.S. EPA 1991). Reduced toxicity indicates oxidants or cationic metals as contributors to overall toxicity of the sample.

4. **EDTA chelation**: Samples are treated with EDTA to chelate divalent cationic metals (i.e., Al^{2+}, Ba^{2+}, Fe^{2+}, Mn^{2+}, Sr^{2+}, Cu^{2+}, Ni^{2+}, Pb^{2+}, Cd^{2+}, Co^{2+}, and Zn^{2+}) (Schubauer-Berigan *et al.* 1993a; U.S. EPA 1991) and render them biologically unavailable for uptake into cell tissues. Reduction in toxicity of the sample after EDTA treatment indicates the above metals are present in toxic concentrations. A fully or partially toxic response indicates that something other than divalent cationic metallic compounds is a contributor to sediment toxicity.

5. **Zeolite treatment**: Samples are manipulated using a zeolite cation exchange resin (Ammonex®, Argent Chemicals) to remove ammonia (Ankley *et al.* 1990; Besser *et al.* 1998; Jop *et al.* 1991; Van Sprang and Janssen 1997). A reduction in sample toxicity is indicative of ammonia as a contributor to pore water toxicity in the precursor sample.

6. **Graduated pH**: Sample pH is manipulated to discriminate between ammonia or hydrogen sulfide as a source for the observed toxicity (Schubauer-Berigan *et al.* 1993a; Schubauer-

Berigan *et al*. 1993b; U.S. EPA 1991). If sample toxicity increases with increased pH (8.8 to 9.1), ammonia is suspected. Conversely, if sample toxicity increases with decreased sample pH (7.2 to 7.8), hydrogen sulfide is suspected.

A. **Low pH**. The low pH manipulation is achieved by adding the buffer 3-N-Morpholino propanesulfonic acid (MOPS; Sigma Chemicals) to result in a 0.4M solution in the 100% pore water samples. The final pH depends on the buffering capacity of the individual pore waters, but generally remains relatively stable (within 0.2 units) during the test.

B. **High pH**. The high pH treatment is produced by adding 1N sodium hydroxide to 100% pore water. The dilution samples generally decrease in pH with increasing dilution (generally 0.1-0.2 per dilution) due to the water dilution.

In addition to the pore water samples from the site, a "spiked" sample consisting of a clean freshwater sample amended with selected CoPCs at concentrations sufficient to produce a toxic sample was prepared and subjected to the TIE treatments. This sample serves as a “positive control” in order to assess the capacity if the TIE treatments to selectively remove toxicity and is treated in the same manner as the study pore water samples. Details about the spiked sample as well as the field sampling, chemical analyses and toxicity testing procedures are provided in Section 2.3, below.

2.3. FIELD SAMPLING, CHEMICAL ANALYSIS AND TOXICITY TESTING PROCEDURES

For the Indian Head TIE Demonstration, sediment sampling, bulk toxicity testing, pore water TIE testing and chemical analyses of sediment and pore water were required. The following sections provide an overview of these tasks; statistical methods to facilitate interpretation of the data are discussed in Section 2.4. Complete details are provided in the Project Work Plan (Appendix D).

2.3.1. Field sampling.

Station positioning. For the present survey, differentially corrected Global Positioning System (DGPS) data were used, where possible, to provide real-time navigation to selected locations to an accuracy of ±3 m. A Garmin 300 Plus GPS receiver was used to obtain raw satellite data and provide vessel position information in the horizontal control of North American Datum of 1983 (NAD83). The GPS receiver was interfaced with a Garmin GBR 21 differential receiver to improve overall accuracy of the satellite data to the necessary tolerances. Because vegetative cover had precluded effective use of GPS for Site 42, coordinates for the TIE stations were confirmed by existing stake locations placed during the previous studies (Appendix C-1).

Field operations were conducted at the Indian Head NSWC area between 10 October and 11 October 2000. Stations were positioned and marked on 10 October with sediments subsequently collected the next day. Station positions in Mattawoman Creek were accessed via a 20-ft workboat and marked with surface floats attached by line to cinder block weights. Test grabs at the locations

were performed to determine bottom type and if suitable samples could be collected. Because the coarse sand/pebble of the original location was unsuitable, Station 4 was moved from the target location and relocated across the creek to fine grained sediments on the opposite bank. Station 11, the furthest downstream at Area 42, located at the mouth of the creek, was moved slightly to the west to encompass what appeared to be a more depositional area. Assistance for sampling Station 11 and the Mattawoman Creek Stations in Area 39/41 was provided by NSWC firemen using their 18 ft workboat. The target location for Station 15 was unsuitably rocky and hence was relocated up the creek to a seep of an old burn site.

After locating the Mattawoman Creek stations, SAIC personnel met with NSWC and Tetra Tech personnel to locate the Area 42 stations. All parties transited to Area 42 and the historic Tetra Tech sampling positions were located by existing marker stakes, and the positions logged using GPS. All stations in Area 42 were verified by Fred Ramser of Tetra Tech.

Sediment collection and on-site handling. On 11 October, SAIC personnel first collected sediments at Area 42 stations and then at stations in Mattawoman Creek (Area 39/41 and Station 15). Undisturbed surface sediment to a penetration depth of 10 cm was collected by either Ponar grab or plastic scoops depending on station location, water depth and sediment type. Five gallons of sediment were collected into pre-cleaned polyethylene buckets at each station for transport to a shore-side location. The water depth at Station 10 in Area 42 was approximately one foot, and hence the Ponar grab was used for sample collection. All other stations in Area 42 were shallower than one foot and thus could be collected with scoops. Prior to sampling and between stations, the grab was decontaminated by sequentially scrubbing with Alconox, 10% nitric acid and methanol rinses, with site water rinses between each step.

Stations 1, 3 and 4 (in Area 39/41) as well as Station 15 were sampled by scoops; no standing water was present at the time of collection. All other stations (2, 5, 6, 7, and 8) were sampled using the Ponar grab. Flash photographs were taken of representative sediment samples to document lithographic features (e.g., redox depth, recent depositional patterns).

Upon completion of the sampling, all samples were placed in plastic drums with ice. The drums were transported via truck, on ice, and were delivered on 12 October to the walk-in cooler facilities of Springborn Laboratories in Wareham, Massachusetts to await subsampling for bulk sediment toxicity (Section 2.3.2) and chemical analyses (Section 2.3.3).

2.3.2. Toxicity Testing Methods.

Bulk sediment toxicity characterization. The freshwater amphipod *Hyalella azteca* was previously chosen for bulk sediment tests at Site 42 and toxicity was observed. *Hyalella* tolerates the full range of grain sizes that might be encountered at the study sites. In this study, the bulk sediment test was conducted as a precursor to the TIE tests, principally to ensure that only samples that exhibited toxicity were subject to further toxicological evaluation.

The 10-day *Hyalella azteca* test (Table 2.3-1; U.S. EPA 1994) was conducted from16 to 26 October 2000. Each sediment sample was homogenized in a mixing drum and subsequently wet-pressed through a 2.0 mm stainless steel sieve to remove any potential predators. The test included eight replicates and twice-daily renewals of overlying water.

Pore water extraction and TIE sample selection. A total of 1800-2000 ml were needed from each sediment sample to provide sufficient water for the TIE and analytical measurements. In order to minimize the sediment holding time, pore water extraction using the syringe method (Winger and Lassier 1991) was initiated on all 15 bulk sediments on 24 October. Personnel re-homogenized the sediments and inserted six 50 ml syringes to extract pore water from each sediment bucket. Individual syringes were filled full in as little as 2 hrs or as long as 10 hours generally depending on the sediment grain size. To expedite pore water collection, as many as 9 syringe units were added to the original six collectors in some of the sediment buckets.

Biological Tests on TIE Treatments. Phase I TIE methods (U.S. EPA 1996) are designed for acutely toxic samples and are based on the use of small test organisms. For riverine sites such as the Indian Head study areas, the freshwater amphipod *Hyalella* and the fathead minnow *Pimephales promelas* were selected as they were considered representative of endemic populations and were also amenable to the tests. Also, *Hyalella* had been used in the previous ten-day bulk sediment tests and thus using this species for the pore water TIE provided a comparative framework for evaluation of results. In the current study, *Hyalella* (7-14 days old) and *Pimephales* (1-2 days old), were obtained from culture stocks at Springborn Laboratories. The juvenile amphipods (7 to 14 days old) used in the test were produced by isolated adults cultured and maintained at Springborn Laboratories.

U.S. EPA procedures for marine TIEs using the amphipod *Ampelisca abdita* were adapted for *Hyalella* and the fish *Pimephales* as outlined in Table 2.3-2. Dilutions were prepared to generate a series of four test concentrations: 10%, 25%, 50%, 100% pore water. Water used for TIE control exposures and dilution waters was the same water used for renewals in the bulk sediment toxicity test. One control treatment is run in parallel with each TIE manipulation. The above experimental design results in a total of seventy-seven toxicity tests (11 samples x 7 treatments) being performed for each of the species tested. Each test is performed in triplicate, and includes an additional water-only chamber to monitor water quality. All exposures are conducted in 25 ml borosilicate scintillation vials (Kimble brand) to a final volume of 20 ml.

A positive control "spiked" sample was prepared by chemically amending a dilution water sample to produce a nominal fluoranthene concentration of 200 µg/L and a measured silver concentration of 44 µg/L in the untreated sample. These concentrations were expected to be toxic to *Hyalella* based on reported LC_{50} values for fluoranthene (44 µg/L, Spehar *et al*. 1999) and silver (6.8 µg/L, Rodgers *et al*. 1997) (Table 3.3-1). Similarly, for *Pimephales*, Gendusa (1990) reports an LC_{50} value of 7.7 µg/L for larvae exposed to fluoranthene (Table 3.3-1), while *Pimephales* larvae exposed to silver (in water with hardness and DOC values in the range of most of the Indian Head samples) yielded a LC_{50} value of 8.5 µg/L (Karen *et al*. 1999). Therefore, the fluoranthene and silver concentrations in the spiked sample were also expected to be toxic to *Pimephales*.

To test for the effectiveness of TIE procedures to alter the toxicity of ammonia, a spiked sample consisting of 140 mg/L of ammonia was added to a non-toxic EDTA treated sample. The concentration was selected such that the total ammonia concentration would exceed the LC_{50} for *Hyalella* (126 mg/L; Besser *et al*. 1998). The spike sample was subsequently split into three fractions and separately treated with low (7.2) pH high (8.9) pH, and zeolite.

Water quality measurements (temperature and pH) were recorded for each sample prior to distribution into the dilution series. During the test, temperature was continuously logged at 5-minute intervals with a 'Tidbit' thermistor/logger unit (manufactured by Onset Corporation). Upon test termination, pH and dissolved oxygen were measured in one animal exposure replicate and in a separate water quality replicate.

2.3.3. Analytical Chemistry Methods.

Sub-sampling for Chemical Analyses. Following re-homogenization on 24 October, the sediments were sub-sampled into clean glass bottles for chemical and physical analyses and airfreighted on ice for overnight delivery to the subcontract laboratory (Severn-Trent Services, Baltimore, MD). On 26 October, a sub-sample of each of the pore waters selected for TIE testing was preserved with 10% nitric acid for subsequent metals analyses. Sub-samples for TOC analyses were preserved with 10% sulfuric acid while sub-samples for DOC analyses were untreated. The metals and the organic carbon samples were stored in clean polyethylene containers and subsequently shipped to the chemical laboratory as described previously for sediments.

Instrumental analyses were performed on bulk sediment and sediment pore water samples from each location. Laboratory analyses of metals, SEM:AVS, PAH, PCB and pesticide contaminants in sediment as well as metals in pore water were conducted according to methods outlined in the NOAA Status and Trends Program (NOAA 1998). These multi-elemental techniques provide sensitive results with a high degree of accuracy and precision (NOAA 1998). Nitroaromatics and nitroamines were measured using high performance liquid chromatography (HPLC) following EPA Method SW8330.

Individual analytes are listed with MDLs in Table 2.3-3. Method detection limits (MDLs) were established for each analyte before analyses were conducted. MDLs were obtained for the procedures outlined in 40 CFR part 136, and in Standard Methods for the Examination of Water and Wastewater (American Public Health Association 1995). Quality control samples were processed along with each batch of samples. Any deviations from QA/QC criteria for each type of analysis are summarized below.

The grain size of the sediment samples was determined by wet sieving through 15 sieve sizes with distilled water per ASTM Method D422. Results were summarized into three size fractions: gravel, sand and fines (silt + clay). The gravel and sand fractions were transferred to pre-weighed evaporating dishes, dried, and reweighed to determine the proportional composition of each size class.

ASTM Method D2260 was used to determine the percent moisture of the sediment samples. These data were obtained prior to sample extraction in order to adjust sample volumes to achieve desired quantitation limits (dry basis) for all sediment samples regardless of moisture content. Samples were stored at 4 ^{o}C (± 2 ^{o}C) prior to analysis. Wet samples are dried overnight (110 ± 5°C) to remove the water.

Measurements were obtained for TOC in the sediments using EPA Method SW9060. Here, the organic carbon in the sample was converted to carbon dioxide (CO_2) by high temperature oxidation, and the CO_2 produced was measured directly by a nondispersive infrared (IR) analyzer. TOC in pore water was analyzed per the same method used in bulk sediment analyses (i.e., EPA Method SW9060), except organic carbon in the sample was oxidized to CO_2 by persulfate in the presence of ultraviolet light rather than by heating of the sample in a furnace. DOC was quantified as the fraction of TOC (per EPA Method SW9060) in the water sample that passes through a 0.45 µm filter prior to analysis.

Sulfides were analyzed per EPA Method SW9034. Here, pore water samples are preserved with zinc acetate to conserve sulfides as a precipitate. Ammonia in pore water was measured using the salicylic acid method (EPA Method 350.2) and an ammonia colorimeter (Hach Method 8038). Unionized ammonia was calculated using the formulas applied by Hampson (1977).
Total Hardness was measured by using the EDTA titrametric method (Hach Method 8226 after EPA Method 130.2) and reported as calcium chloride equivalents.

Alkalinity was measured by SAIC using the phenolphthalein and methyl orange titration method (Hach Method 8221, conforms to EPA Method 310.1), and is reported as calcium carbonate.

2.4. STATISTICAL ANALYSES

Survival results for each of the TIE treatments in each dilution series was used to generate LC_{20} and LC_{50} values. These values were calculated by linear interpolation, and confidence intervals were generated by the bootstrapping technique. ToxCalc software (version 4.0.8, Tide Pool Scientific Software, 2000) was used to generate test statistics including a test for normality of the distribution of the data (Shapiro-Wilkes test). Results from each dilution were evaluated by ANOVA followed by Dunnett's test to detect statistical differences from controls.

In the present study, the primary method used to describe the magnitude of toxicity is the statistical estimate of the concentration of pore water required to cause, for example, a 20% reduction in survival of animals in the treatment, called the Lethal Concentration – 20% (LC_{20}). While the equivalent LC_{50} values were also calculated, the LC_{20} values proved to be a more sensitive gauge of changes associated with the TIE manipulations on the toxic samples. Also of importance was the actual survival responses observed in individual dilutions of a treatment series (10, 25, 50, and 100% pore water concentration). Here, estimation of the LC_{20} data was not always possible since a partial mortality result in two or more treatments is required for accurate calculation.

3. RESULTS

3.1. CHEMICAL CHARACTERIZATION OF SEDIMENTS AND PORE WATERS

Results from laboratory analyses of sediments (Appendix A-1-1, A-1-4) and pore water metals (Appendix A-1-2) as well as predicted pore water concentrations for organics (Appendix A-1-3) have been converted into HQs (Appendices A-2-1 and A-2-2, respectively) through normalization to the respective sediment and pore water benchmarks as discussed in Section 2.1. A brief summary of the HQ results is presented here; a more detailed discussion is incorporated into the toxicity results addressed in Sections 3.2 and 3.3.

Interpretive summaries for sediment and pore water HQs can be found in Table 3.1-1 and Table 3.1-2, respectively. Results were categorized in manner deemed useful for prediction of acute toxicity responses in the TIE treatments: A concentration above the acute threshold (HQ>1) suggests possible exposure-response relationship ("+"), while elevations that are three-fold and ten-fold above the benchmark indicate likely ("++") and probable ("+++") acute toxicity, respectively.

The sediment HQ calculations show that twelve of 15 stations had at least one analyte above the sediment benchmark (Table 3.1-1). Analytes showing the most common exceedences and highest HQs were silver (6 stations), PCBs (9 stations) and beta-BHC (8 stations). In contrast, PAH exceedences were observed only two stations (Stations 5 and 13) while SEM:AVS data suggest that toxicity of divalent metals was also likely at only two stations (Stations 9 and 15).

HQs derived from pore water concentrations (Table 3.1-2) indicated that manganese exhibited the most frequent elevations above the acute benchmark (nine stations, with Stations 6, 8, and 11 indicating highest probability of risk) followed by silver (5 stations, particularly Stations 1 and 2) and beta-BHC (4 stations; particularly Stations 1 and 2). Other notable exceedences were for zinc (Stations 1 and 15), gamma chlordane (Station 2) and copper (Station 1). Neither PAHs nor PCBs exceeded the benchmarks.

Grain size analyses results compiled into three size fractions, gravel, sand and fines (silt + clay), are presented in Appendix A-4-1 (supporting particle size data in Appendix A-4-2). The majority of the stations contain fines greater than 50%, except for several stations (Stations 1, 2, 3 and 15) that contain a considerable sand component. Moisture content of the samples was variable, ranging from 8-76%.

3.2. BULK SEDIMENT TOXICITY RESULTS

Results of bulk sediment survival with *Hyalella* were used in conjunction with chemistry results discussed above to select the pore waters to be used for the TIE investigation. Springborn Laboratories reported that the Laboratory Control organism performance in the bulk sediment test did

not strictly meet acceptance criteria (i.e., 79% vs. 80%; Appendix B-1). However, for the purposes of the present investigation, the results were deemed sufficient to provide a basis for selecting TIE samples.

Survival of *Hyalella* in the 15 bulk sediment samples ranged from 0% to 53% (Table 3.2-1). In the sediments from Area 39/41 (Stations 1 through 8) and Station 15 (not in Area 39/41), survival ranged from 20% to 53% except for Station 15, where survival was 0%. In the sediments from Area 42 (Stations 9 through 14), survival ranged from 0 % to 33%. These results are similar to those reported by Tetra Tech (1999b), where survival of *Hyalella* in twelve sediments from Site 42 ranged from 9% to 53%. Because all sediments were toxic, other criteria such as representation of spatial distribution and representation of different classes of elevated contaminants were used to select pore waters for TIE testing. Of the eight stations sampled from Area 39/41, five were selected (Stations 1, 2, 5, 6, and 8) as well as upstream Station 15. Four of the five sampled stations from Area 42 were also selected (Stations 10, 11, 12, and 13). The *Hyalella* results from the untreated pore water exposure portion of the TIE are also presented in Table 3.2-1. Differences in the occurrence of toxicity are apparent between sediment and pore water tests for five Stations (1, 5, 8, 10, 12) with the pore water test being less sensitive of the two. These differences are discussed further in Section 3.3.

In the reporting of the Tetra Tech study (Tetra Tech NUS, 1999b), a correlation between toxicity and ammonia measured in overlying laboratory exposure water was found and interpreted as evidence for support of ammonia as a principle source of toxicity. In the current study, the measured overlying ammonia concentrations in the bulk sediment toxicity tests were considerably lower than they were in the Tetra Tech NUS study, with the highest measured value at 2.2 mg/L, and only one other measurement were greater than 1.0 mg/L (Table 3.2-2). By comparison, half the samples in the previous study had overlying water values greater than 5 mg/L. This suggests that ammonia in the overlying water is not a reliable indicator of sediment toxicity in the present investigation. Total Organic Carbon concentrations in the sediment and in pore water samples are also presented in Table 3.2-2. It is evident that the range in TOC concentrations between stations is much larger in sediments than in pore waters and the two are uncorrelated (see ratios, Table 3.2-2). For example, Station 2 had the lowest percent TOC in the sediment, and the highest TOC in extracted pore water. Wide ranges in DOC, total ammonia, sulfides and hardness in pore water were also observed. These station-specific differences in the non-CoC chemistry of the pore water samples are believed to have important implications regarding the observed trends in sediment and pore water toxicity.

3.3. TIE RESULTS

The interpretation of TIE toxicity responses is based on both the observed magnitude of the toxicity in the treated sample as well as the relative change in toxicity from the previous sample result in the TIE sequence. Hence, the toxicity data is synthesized and presented in several formats to assure that patterns and trends in the results are effectively discerned. Supporting lines of evidence are obtained from the interpretation of individual dilutions responses of a given TIE treatment (Appendix B-2), with assistance from plots of mean survival responses versus pore water concentration (Appendix B-3), and finally, calculation of statistical endpoints that estimate dilutions (pore water percentage) that would

result in specific levels of mortality ('LC' values; Appendix B-4), including corresponding 95% confidence limits for each treatment.

In the sections below, results of Quality Assurance/Quality Control (QA/QC) procedures are presented first to assess the efficiency of the treatment procedures and the sensitivity of the test species to the CoCs and confounding factors expected to be encountered at the site (Section 3.3.1). Next, an interpretive summary of the TIE responses is presented to provide the reader with an overview of the study findings (Section 3.3.2). Finally, an in-depth analysis of the treatment responses in conjunction with the associated chemistry data is presented to identify specific chemicals or confounding factors as the toxicity source, where possible (Section 3.3.3). This section also includes discussion of uncertainty in the conclusions drawn.

3.3.1. Quality Assurance Results.

Completeness. All *Hyalella* exposures were conducted as described in the Work Plan. *Pimephales* were available in limited supply at the beginning of the exposures due to an unexpected shortage at the culture facility. Accordingly, the available animals were distributed to pore water fractions addressing CoC toxicity (i.e., all exposures through EDTA treatment). Additional fish were subsequently obtained within two days, and were used to complete the zeolite exposures that remained toxic following EDTA treatment.

Performance controls. For *Hyalella,* TIE performance controls were highly successful, with 100% survival in all treatments except the high pH treatment where a reduced survival of 60% was observed. Data from the high pH treatment has been retained in the synthesis of results because they complement the evidence presented for the low pH and zeolite treatments used to infer the potential for ammonia toxicity.

For *Pimephales*, performance control survival was also largely successful with >90% survival in all treatments except for a significant decrease in the zeolite treatment (20%). This appeared related to the separate batch of animals that were used and hence the zeolite data was not retained because of this poor control performance.

Spiked sample results. A spiked sample containing silver and fluoranthene was subjected to TIE treatments and toxicity tests conducted with *Hyalella* and *Pimephales* in order to assess the relative sensitivity of the two species as well as to demonstrate the effectiveness of the TIE manipulations.

For *Hyalella*, the initial untreated sample was toxic to 100% of exposed organisms at all dilution levels (Appendix B-2) and the C_{18} treatment did not increase *Hyalella* survival. However, the sodium thiosulfate ($Na_2S_2O_3$) treatment removed all toxicity, yielding LC_{20}values >100%. From these results, it is assumed that although the fluoranthene-related toxicity was removed by the C_{18} treatment, the sample remained completely toxic because of the silver component in the sample. This suggests that the treatment process would need to be reversed such that silver was removed first in order to measure the effects of fluoranthene.

For *Pimephales*, the initial untreated sample was also toxic to 100% of exposed organisms at all dilution levels (Appendix B-2). However, in contrast to *Hyalella*, *Pimephales* showed a reduction in toxicity following the removal of fluoranthene as the LC_{50} changed from <10% prior to C_{18} treatment to 18.5% after C_{18} treatment. With fluoranthene removed, the LC_{50} for silver was calculated as 8.1 µg/L (LC_{50} = 18.5% x 44.5 µg/L), which is in good agreement with the literature LC_{50} value. Complete survival was obtained after $Na_2S_2O_3$ treatment (LC_{50} >100%), demonstrating the effectiveness of this procedure to remove toxicity associated with silver in the sample.

A spiked sample containing ammonia was also tested to assess the ability of the TIE procedures to discern ammonia effects. After zeolite treatment, total ammonia in the 100% spiked sample was reduced to 5 mg/L and the *Hyalella* LC_{50} indicated the sample was completely non-toxic (Table 3.3-1). These data indicate that the procedure is effective in removing large quantities of ammonia from a sample. Also, the high pH sample results increased toxicity as expected (LC_{50} = 6.8 mg/L), while the low pH treatment reduced toxicity (LC_{50} = 11.5 mg/L; Table 3.3-1). Given that the total ammonia concentration in the spiked sample remained unchanged, the reduction in toxicity from the high to low pH treatments is attributed to the decrease in unionized ammonia exposure and demonstrates that pH adjustments provide data that can corroborate the role of unionized ammonia in the toxicity of the sample.

3.3.2. Summary of TIE Results by Treatment.

An interpretive summary of the TIE principal findings for *Hyalella* is provided in Table 3.3-2. The LC_{20} values are assigned symbols to represent degrees of toxicity and change associated with each manipulation; samples with LC_{20}< 10% have been categorized as having high toxicity ("+++"), LC_{20}values between 10% and 40% are designated moderately toxic ("++"), values between 40-80% as slightly toxic ("+") and values greater than 80% are designated non-toxic ("NT"). Also contained in Table 3.3-2 are large and small triangles indicating large and small changes in toxicity in the treatment relative to the previous treatment, with the arrows indicating the direction of movement in the toxicity trend (downward pointed arrow indicates reduced toxicity).

The results show that the TIE process eliminated toxicity as designed (with the exception of one station, as discussed below); that is, one or more of the TIE manipulations removed the potential sources of toxicity. Reponses observed for *Hyalella* in each of the manipulation steps are discussed below; a discussion of results for both *Hyalella* and *Pimephales* by individual station is presented in Section 3.3.3.

Untreated Pore water toxicity. Of the ten untreated pore waters tested, four of six samples in the Site 39/41 area were toxic (Station 2, 6, 8, 15) while in Area 42, two of four stations were toxic (Stations 11, 13). Stations 2 and 15 were highly toxic (with LC_{20}< 10%), Stations 6, 8, and 11 were moderately toxic (LC_{20} = 32%, 21%, and 20%, respectively) and Station 13 was low toxicity (LC_{20} = 72%, Table 3.3-3). For the remaining four pore water samples (Stations 1, 5, 10, and 12), the untreated pore water LC_{20} values were > 100% (not toxic). Toxic samples were further tested with

subsequent treatments described below to resolve which of these chemicals were responsible for the toxicity.

Filtration. Filtration of the four Area 39/41 samples (Stations 1, 5, 10, and 12) had no effect on sample toxicity, but the process did appear to remove the toxicity for both stations (Station 11 and 13) at Site 42 (Table 3.3-2). Reduced toxicity observed for Station 11 is based on an estimated LC_{20} value given findings of statistically significant toxicity reductions observed in the 25% and undiluted (100%) samples (Table 3.3-3, Appendix B-2). For Station 13, the slight toxicity observed in the untreated sample was removed entirely by filtration. These results suggest that some of the toxicity in the pore water from these two stations was due to components of the particulate fraction, either from contaminants associated with particulates or presence of confounding factors (e.g. sulfides, Table 3.3-2). These possibilities are discussed further in Section 3.3.3.

C_{18}. For the five samples with residual toxicity after filtration, the treatment of the filtered pore water sample with the C_{18} column to remove organic compounds was generally not effective in reducing toxicity (Table 3.3-2). Only at Station 6 was some C_{18} effect evident, as reduced toxicity for both the 50% and 100% dilutions was observed. In general, the lack of toxicity reduction due to C_{18} treatment is consistent with typically negligible concentrations of sediment and pore water relative to benchmarks (Table 3.1-1, 3.1-2).

$Na_2S_2O_3$. The treatment of pore water with $Na_2S_2O_3$ to remove selected metals (Cd^{2+}, Cu^{2+}, Ag^{2+}, Hg^{+}) was applied to the five toxic samples remaining after C_{18} treatment. None of the samples showed substantial reduction in toxicity due to this treatment, and thus metals such as silver do not appear to be primary drivers of toxicity in the samples (Table 3.3-2) and, in general, pore water benchmark exceedences for the identified analytes were not observed. A notable exception was noted for Station 2, as the lower dilution samples (10% and 25%) did exhibit toxicity reduction in response to $Na_2S_2O_3$ treatment. A more detailed analysis of the data does suggest a minor role for silver toxicity; this and other possibilities are discussed further in Section 3.3.3.

EDTA. Of the five remaining toxic samples (Stations 2, 6, 8, 11 and 15), reductions in sample toxicity due to the EDTA treatment was noted in samples from Stations 6 and 15 from Area 39/41 and Station 11 from Area 42 (Table 3.3-2). Of these, the reductions observed at Station 15 were most consistent with Zinc toxicity given the high HQs observed for sediment (HQ=42, Appendix A-2-1) and pore water (HQ=208, Appendix A-2-2). Stations 6, 8 and 11 had uniquely high HQs for manganese in pore water while other metals were not above their respective benchmarks. Following EDTA treatment, complete reduction in toxicity was observed for Stations 6 and 11 while partial reduction was observed for Station 8 (Appendix B-2). Hence it is concluded that manganese was a contributor to pore water toxicity at these stations. Other CoCs may have also played a minor role in the observed toxicity; this is discussed further in Section 3.3.3.

Zeolite. Treatment with zeolite to remove ammonia was applied to the two samples from Stations 2 and 8 that had residual toxicity after EDTA treatment. Zeolite treatment did result in reduction of toxicity at both locations, but of the two, the response observed at Station 8 was the most consistent

with reduction in ammonia effects. Here, the sample prior to treatment had unionized ammonia of 7.2 mg/L (Appendices A-3-1 and A-3-2), a value that is 18-fold above the acute criteria (Table 3.3-5). The sample became completely non-toxic after the zeolite treatment; hence ammonia is strongly implicated as the source of toxicity in this sample. Station 2, in contrast, exhibited toxicity reduction only for the low dilution (10% and 25%) samples (Appendix B-2) and the sample did not have elevated ammonia concentrations (Table 3.2-2). Hence it is concluded that factors unrelated to ammonia are a source of toxicity in this sample; additional possibilities are discussed further in Section 3.3.3.

Low/High pH adjustment. The adjustment of pH was also performed on Stations 2 and 8 that exhibited residual toxicity after EDTA treatment in order to confirm the results suggested by zeolite with regard to the potential for ammonia toxicity. Of the two stations, the response observed at Station 8 supported the conclusion that ammonia was the cause of toxicity; reduced pH removed toxicity while higher pH did not (Table 3.3-2). For Station 2, however, low/high pH did not affect the toxicity of the sample, and thus the source of toxicity could not be resolved. Possible explanations for this result are discussed in Section 3.3.3.

Summary. In summary, the TIE process was successful in resolving all sources of pore water toxicity with only one exception (Station 2). Toxicity was reduced in two samples following filtration; however, the filtration-related results offer no clear interpretation because the filter may retain particulates and colloidal aggregates from multiple classes of contaminants. The C_{18} manipulation did not generally result in toxicity changes in any of the pore waters, indicating that non polar organics were generally not the primary contributors to acute toxicity. A potential role for polar organics is suspected in the case of Station 2 where all the toxicity was not removed by the TIE treatments and high concentrations of beta-BHC were observed.

The principal TIE signals that were observed suggest a role for metals and ammonia as a source of toxicity. The $Na_2S_2O_3$ treatment did suggest that silver was a partial source of pore water toxicity at Station 2, but generally the other targeted metals (Cu, Cd, Ag, Hg) were not present at acutely toxic concentrations. The EDTA treatments revealed that manganese at Stations 6, 8 and 11 and zinc at Station 15 were sources of pore water toxicity. Finally, appeared to be a source of acute toxicity at Station 8 given the zeolite toxicity reduction and confirmatory pH responses.

3.3.3. TIE Results by Station.

In the following section, TIE results are reviewed in detail with respect to results from chemical analyses. Positive results (from manipulations that resulted in changes in survival) are generally presented first in the order of the TIE manipulations followed by non-toxic samples and finally the potential for pore water toxicity for those samples not selected for TIE testing.

Toxic TIE Stations (2, 6, 8, 11, 13, 15). In the following paragraphs, a detailed discussion of observed toxicity and chemistry is provided for samples found to exhibit toxicity in the TIE testing. This analysis often relies upon inspection of results from individual dilutions, as well as differences between dilutions to discern the nature of the toxic effect.

Station 2. Station 2, located in Site 39/41, was set approximately 30 ft offshore between Stations 1 and 3, and was chosen to examine potential small-scale spatial variability in CoC distribution and toxicity. The depth was approximately 6 ft at the time of sampling. The bulk sediment from this station was found to be toxic to *Hyalella* (53% survival; Table 3.2-1).

The untreated, filtered and C_{18} pore water samples exhibited complete toxicity to *Hyalella* (Table 3.3-3). In the subsequent TIE treatments ($Na_2S_2O_3$, EDTA, zeolite, and pH), complete toxicity was again observed throughout the 50% and 100% dilution samples such that it was not possible to infer the source of the toxicity for these most concentrated samples (Appendix B-2). However, the $Na_2S_2O_3$ treatment did result in a partial (one-third) toxicity reduction in the lowest concentration sample (10%), and the subsequent zeolite and low pH treatments removed the remaining toxicity. In the 25% dilution, the zeolite and low pH treatments also proportionately reduced the toxicity (as would be expected given the higher exposure concentrations). Results for *Pimephales* were similar to that of *Hyalella* (Table 3.3-4). Complete toxicity was again observed throughout the 50% and 100% dilution samples. Also, in the lowest concentration sample (10%), $Na_2S_2O_3$ treatment resulted in nearly complete (93%) toxicity reduction, while in the 25% dilution the zeolite treatment resulted in partial removal of toxicity.

Given the $Na_2S_2O_3$ results observed in the lower dilutions for both species, it is concluded that certain metals (Cd^{2+}, Cu^{2+}, Ag^{1+}, or Hg^{2+}) were involved in the toxic response. Of these, silver had a high pore water HQ (10.1), and was the only metal present at acutely toxic concentrations (e.g., HQ > 1). Thus, silver is strongly implicated as a contributor to the pore water toxicity at this location. In contrast, the reduced toxicity responses observed with the zeolite and low pH treatments for both species that would normally be explained by ammonia removal was unsubstantiated by the measured ammonia concentrations that were well below toxic levels (Table 3.3-5). Hence, further investigation as to the source of the residual toxicity is presented below.

Atypically high pore water hardness (170 mg/L as $CaCO_3$) was noted for this sample and this may suggest that adverse, non-CoC chemistry conditions may be involved in the sample toxicity. zeolite was found to reduce toxicity in the lower dilution samples. Because zeolite is added to pore water to induce cation exchange (targeted for ammonium ions) and removal from solution, this process may also have exchanged other cations (e.g., sodium, potassium, calcium, magnesium) such that hardness was reduced to amounts tolerable for organism survival. The observed pH effects could be similarly explained by pH driven ionic changes in the pore water chemistry. The reason why zeolite and low pH effects did not reduce toxicity in the higher dilutions is unknown but may have been because the ionic imbalances are too great in the higher dilutions to be reversed by these treatments.

Another view of the Station 2 results is that insufficient quantities of the chelating agents were available to sequester all of the available toxicants such that toxic concentrations were carried into subsequent treatments. For the identified CoC, silver, this scenario seems unlikely because the silver concentration in the spiked sample (44 µg/L) was effectively sequestered to remove toxicity and this concentration was greater than that measured for Station 2 (31 µg/L). Hence it was reasoned that the residual toxicity could be due to other chemicals that were not effectively removed by the TIE treatments. In particular,

the more polar organic chemicals including the pesticides were suspect because the C_{18} column does not efficiently remove them, and at
Station 2, extremely high sediment (HQ = 9,264) and pore water (HQ=35,063) benchmark exceedences for beta-BHC were observed[1]. Other polar pesticides including alpha- and gamma-chlordane and delta-BHC also had high pore water HQs (35, 4.5 and 1.9, respectively) such that the location is generally high for this chemical group. Hence, a failure to remove these compounds from the pore water sample would explain the residual toxicity.

Finally, the unique nitrobenzene concentration (1056 ng/g) observed at Station 2 suggested novel exposure conditions that could be related to sample toxicity. Nitrobenzene toxicity is not suspected as the estimated pore water concentration (1.7 mg/L) for this sample is at least an order of magnitude below the expected threshold for acute effects (Manchini, 1992; T. Bridges, USACE, WES; personal communication). However, it was also noted during the treatment of the pore water sample that the filtration required several hours and more filters than the other samples. This suggests unusual geotechnical/ geochemical properties of the water or associated particulates that might have contributed to toxicity.

Station 6. Station 6 in Area 39/41 was chosen because of the presence of elevated PAHs and metals (including silver). The station was located mid-channel in Mattawoman Creek at a depth of approximately five feet. The sediment was observed to be a mixture of sand and soft mud. Survival of *Hyalella* in the bulk sediment test was 54%.

Reduced survival of *Hyalella* was seen in the untreated pore water for the 100% (28% survival) and 50% (50% survival) dilutions (Appendix B-2). In the subsequent TIE manipulations, filtration did not significantly alter toxicity to *Hyalella*, but C_{18} results did suggest a trend of reduced toxicity (increases in survival from 53 to 87% and 18 to 33% for the 50 and 100% dilutions, respectively, were observed but were not statistically significant). However, the C_{18} treatment trends were not supported by evidence of high organic chemical concentrations in pore water, and thus the potential role of organic contaminants as a source of toxicity in the sample was discounted. The next TIE treatment, $Na_2S_2O_3$, had no effect, but following EDTA chelation, survival improved from 0% to 87% in 100% dilution. This result implicates cationic metals other than those addressed by (i.e., not Cd^{2+}, Cu^{2+}, Ag^{1+}, or Hg^{2+}) as a contributor to acute toxicity.

Untreated pore water results for *Pimephales* were similar to that observed for *Hyalella*; toxicity was observed only in the 100% (0% survival) and 50% (30% survival) dilutions (Appendix B-2), while reduction in toxicity was observed with filtration of the 50% dilution (85% survival) and $Na_2S_2O_3$ had no effect. Unlike *Hyalella*, however, toxicity of the 100% sample was not affected by subsequent TIE treatments.

[1] For beta-BHC, higher UET benchmarks are reported for similar compounds (technical-grade BHC, 100 µg/kg; gamma-BHC, 9 µg/kg; (NOAA 1997)), but even using the highest of these values a significant toxicity concern for this chemical is still apparent. For chlordane, a comparison of the sediment concentration against the UET benchmark (30 µg/kg; NOAA 1997) and would again indicate a probable toxicity concern.

As observed for Station 2, the *Hyalella* response to the EDTA treatment in conjunction with the high manganese pore water (HQ = 17) and otherwise low metals suggests that manganese is a likely source of metal toxicity. The divalent metals probably do not play a significant role given that the SEM-AVS value (1.7 µM/g), although positive, is below the 5 µM/g threshold for effects. It is notable that this sample had the highest total ammonia concentration (37.5 mg/L; WQC-HQ = 17.2, Table 3.3-5) but since all the residual toxicity to *Hyalella* was removed prior to zeolite treatment, it is likely that ammonia was not directly toxic although could have acted to enhance the toxicity of metals (Wood *et al*., 1999).

Station 8. Station 8 was located eastward and downstream from Site 39/41, across the channel, and adjacent to the bank of the vegetated mud flat that delineates the channel. The site was originally chosen for its elevated mixed metals. *Hyalella* survival in the bulk sediment test was 33%.

For *Hyalella*, mortality ranging from 27% to 73% was observed in the three higher concentrations (25%, 50% and 100% concentrations). The marginal toxicity observed in the 25% dilution (73% survival) was removed after filtration (92.9% survival). Hence, some toxicity was associated with the particulate fraction. In the remaining 50% and 100% dilutions, toxicity was partially reduced after EDTA treatment (from 13 to ~55%), and fully eliminated when treated with zeolite. Thus ammonia appears to be the major source of observed effects.

Like *Hyalella*, the majority of the toxicity to *Pimephales* was observed in the higher dilutions (50% and 100% concentrations), and none of the treatments clearly improved survival. Potential toxicity reduction was observed in the 50% dilution after $Na_2S_2O_3$ treatment (increase from 0% to 40% survival), although this result was discounted given higher toxicity in the subsequent treatment (EDTA) and the general lack of metals as a toxicity source. Here, only silver was slightly above acute concentrations (HQ = 1.1) in pore water and SEM-AVS was negative (-1.0 µM). There was an HQ of 24 for manganese in the pore water, but chelation with EDTA did not reduce toxicity. Hence, it is unlikely that silver was contributing toxicity to *Pimephales* in this sample such that the residual toxicity remains unresolved.

Station 11. Station 11 was located at the mouth of the stream in Area 42. It was chosen for the TIE study to represent a potential depositional location for contaminants from Area 42 and for elevated concentrations of divalent metals that were measured in the previous studies. Survival of *Hyalella* in the bulk sediment exposure was 8%.

In the untreated pore water exposures partial toxicity (27-71% survival) to *Hyalella* was observed in all but the 10% dilution (100% survival). The filtration step removed the minor toxicity in the 25% dilution as survival increased from 71% to 100%. A reduction in toxicity from filtration was also observed for the 100% treatment (89% survival) but this result was uncertain, as it was inconsistent with the 50% dilution result. Still, the result does suggest that the particulate fraction in the sample is a potential source of the toxicity.

The remaining improvement in survival was in response to $Na_2S_2O_3$ and EDTA chelation after which survival improved to 92% for both the 50% and 100% dilutions. The effects due to $Na_2S_2O_3$ and

EDTA are difficult to separate, but taken together, the response suggests metals as a source of toxicity. Among the metals exceeding pore water benchmarks are chromium (HQ = 23), silver (HQ = 1.2) and manganese (HQ=23). SEM metals (including silver) measured for the TIE study were present and comparable to the historic data (1.8 µM vs. 2.1 µM), however SEM-AVS was negative (-3.0 µM), and thus these metals would not be expected to result in toxicity. Thus, the data suggest that chromium may be a source of toxicity at this location.

For *Pimephales*, 100% survival was observed in all but the 100% concentration where complete mortality was observed. Complete mortality persisted through the remaining treatments, such that the source of toxicity could not be discerned.

Station 13. Station 13 was located the furthest upstream of the six sampled stations in Area 42. It was selected to represent a site that had relatively high PAH and PCB and ammonia concentrations that were higher than at any other station in the study area, based on previous sampling. The bulk sediment test with *Hyalella* resulted in 24% survival.

For *Hyalella*, partial toxicity was observed only in the untreated, full-strength pore water sample (100% dilution) where survival was 63%. Filtration of this sample removed all of the remaining toxicity. No effects on *Pimephales* were observed in the untreated pore water.

The sediment and pore water HQs for metals were uniformly less than unity, and although the sample had excess SEM relative to AVS (1.8 µM/g), the value was less than the benchmark (5 µM/g) for toxic effects. Concentrations of the organics also did not exceed the sediment or pore water benchmarks. Hence, both metals and organics are discounted as a source of toxicity at this location.

Differences in toxicity were observed between the bulk sediment and the pore water test with the former being much more toxic. Hence, the lack of pore water toxicity calls for explanation. This station did have one of the two highest total sulfide concentrations measured for the TIE study, and differences in sulfide exposure between the tests may account for the discrepancy since the pore waters collected for sulfide analysis were immediately fixed with zinc acetate upon collection, the test exposure pore waters were constantly exposed to air, promoting volatilization and oxidation. Also, the pH in the bulk sediment test (6.9) would result in a much higher percentage of hydrogen sulfide (the more toxic sulfide form) than would occur at the pH of the pore water exposure (8.6). Hence, a much higher hydrogen sulfide exposure would be expected to occur in the bulk sediment relative to pore water and thus would explain the toxicity differences.

Station 15. Station 15 was located in Mattawoman Creek, near Slaven's dock, considerably upstream from Area 39/41. It was chosen to replace the originally selected location for
Station 15 because the sediment was rocky and unsuitable for sampling. The current site was selected opportunistically to evaluate a seep originating from a former on-shore burn pit operation. Complete mortality of *Hyalella* in bulk sediment collected from this location was observed.

For *Hyalella*, complete mortality was observed in the untreated pore water samples as were nearly all samples treated with filtration, C_{18} and $Na_2S_2O_3$. In contrast, EDTA chelation eliminated all toxicity to *Hyalella* in all the dilutions. Results observed for *Pimephales* were nearly identical to *Hyalella*; complete mortality was observed in the untreated sample as well as all TIE samples through $Na_2S_2O_3$. After treatment with EDTA, toxicity was completely eliminated.

The above EDTA results strongly implicate cationic metals as the source of toxicity other than those addressed by $Na_2S_2O_3$ (i.e., not Cd^{2+}, Cu^{2+}, Ag^{1+}, or Hg^{2+}). Among the candidate metals found to exceed benchmarks (Ni^{2+}, Pb^{2+} and Zn^{2+}), the measured pore water concentration of zinc (25,000 µg/L) was most conspicuous, being more than 200-fold above the acute criteria. Also, high SEM-AVS (270 µM/g) was observed, with zinc contributing the substantial fraction to the SEM sum. Although minor by comparison, lead in the pore water also exceeded the acute criteria (HQ= 2.5). Because other metals, PCBs, PAHs and pesticides were all measured at low concentrations, it is concluded that zinc and to a lesser extent lead are the sources of toxicity at this station.

Non-Toxic TIE Stations (1, 5, 10, 12). In the following paragraphs, a detailed discussion of chemistry is provided for samples not found to exhibit toxicity in the TIE testing.

Station 1. This station location is an intertidal sandy beach-like sample. The site was chosen for the study because it had the highest silver concentration from all of the historic Indian Head data. *Hyalella* survival in the bulk sediment test was 28%.

No mortality to *Hyalella* or *Pimephales* was observed in pore water exposures. Pore water concentrations of silver, zinc, and lead were 33.1, 607 and 142 µg/L, respectively. These values are 8.1-fold, 5.1-fold, and 2.2-fold above the respective Freshwater Acute Aquatic Life Criteria threshold for silver (4.1 µg/L), zinc (110 µg/L) and lead (65 µg/L). For silver, the measured concentrations are four-fold above the acute toxicity level for *Pimephales* larvae (8.5 µg/L; Karen *et al*., 1999) and five-fold above the LC_{50} for *Hyalella* (6.8 µg/L; Rodgers *et al.*, 1997) Hence, from the pore water data, the samples would be expected to be toxic due to metals, particularly silver. In the present sample, however, the SEM-AVS value was low (0.94 µM/g) and less than the 5 µM threshold value for toxicity. Another potentially important property of silver in sediment that might reduce its toxicity relative to pore water is that this metal is often colloidally bound (either to large macromolecules or particles), and the majority of operationally defined 'soluble' Ag (I) may occur in the colloidal phase (Bell and Kramer, 1999).

Other factors, including sulfides, dissolved and particulate organic matter, chloride and even enzymes systems in the biota themselves may have resulted in reduced sediment toxicity relative to pore water (see review paper by Ratte, 1999). Evidence for high colloidal content of the sample is seen in the high concentration of DOC as a percentage of pore water TOC (87%) relative to other locations in the study. The pore water DOC was also high relative to the sediment TOC concentration. It is also unclear how a sample with low sediment TOC (0.5%) could have higher DOC than samples with high TOC (e.g., Stations 5 and 10, at 12.6% and 11.8%, respectively). These facts suggest unstable and

high anomalous pore water chemistry conditions that have buffered the potential effect of metal toxicity in pore water.

It is recognized that the bulk sediment was toxic to *Hyalella*. With regard to the organic CoPCs, sediment HQs were generally low, and thus toxicity to organic contaminants would not be expected. The sediment HQ for silver was slightly above unity (HQ=1.1), and uptake of silver can occur from bound forms of the metal (Yoo *et al*., 2000) even where pore water concentrations are minimal and SEM-AVS is less than unity. Thus, while acute effects have not been associated with pore water, chronic effects of silver may have occurred in the long term bulk sediment exposures.

Station 5. This station was located proximal to a former transformer storage facility. It is also directly west of a scrap yard, at a water depth of approximately five feet. It was chosen for having relatively high total petroleum hydrocarbons measured during previous investigations along with elevated mixed metals, but also relatively low silver concentrations. *Hyalella* survival in the bulk sediment test was 43%.

In pore water tests, no toxicity to *Hyalella* was observed but toxicity to *Pimephales* was observed only in the 100% dilution. This sample continued to exhibit complete toxicity through the filtration and C_{18} treatments such that organics are not a likely source of the observed effects. This finding is consistent with the observation that although sediment PAH concentrations were high compared to other stations and above sediment benchmarks in some cases, the associated pore water HQs were substantially below effects levels due to the high organic carbon content (12.6%).

In contrast to the pore water treatments, the $Na_2S_2O_3$ treatment of the100% dilution sample did significantly increase *Pimephales* survival (87%). This response implicates the $Na_2S_2O_3$-affected cationic metals (Cd, Cu, Ag) as responsible for the observed toxicity. Of these metals, only silver had a relatively high pore water HQ (0.9), but SEM-AVS was negative, such that the chemistry results are contradictory. Other aspects of the sample chemistry including hardness, ammonia and DOC/TOC concentrations were within the normal range. Overall, the general lack of toxicity in pore water is consistent with both the sediment and pore water chemistry findings such that the bulk sediment toxicity results may be attributed to physical properties of the sediment or perhaps chemicals in sediment that were unmeasured and do not partition into the pore water.

Station 10. Station 10 was located in the rippling stream in Area 42, near a rock pile in close proximity to the steam line that runs through the site. It was chosen to represent a sediment type that is elevated mixed metals. The bulk sediment was highly toxic to *Hyalella* (1% survival).

No mortality to *Hyalella* or *Pimephales* was observed in pore water exposures. Elevated levels of metals in sediment were observed only for silver (HQ=5.6), but corresponding pore water concentrations were low (PW HQ = 0.6) and the SEM-AVS value was negative (-1.9) suggesting that the cationic metals in the sediment including silver are not bioavailable. Also, the sediment and pore water concentrations of the organics were also below levels expected to cause acute toxicity.

The ammonia acute criterion was exceeded (HQ=3.3) but was less than the threshold value measured for this study (HQ=0.14). However, the pore water concentration of total sulfides was higher (44.6 mg/L) in this sample than in any of the pore water samples. As noted for Station 13, sulfide is more likely to persist at elevated concentrations in the sediment exposures than in the water-only TIE. Thus, high sulfide concentrations in sediment that did not carry forward into the pore water exposures could explain the disparity between sediment and pore water toxicity responses.

Station 12. Station 12 was located slightly upstream from Station 10 and was selected for sampling in the TIE study because data from previous monitoring indicated the highest concentrations of silver were observed in this vicinity. The bulk sediment exposures resulted in 0% survival for *Hyalella*.

The untreated pore water was non-toxic to both *Pimephales* and *Hyalella*. Silver concentrations in sediment were above the benchmark (HQ=5.5) but the pore water (HQ=0.5) and SEM-AVS value (-9.2 µM) again suggest that this metal is not the source of toxicity. PCBs, PAHs and pesticides were all measured at low concentrations relative to sediment benchmarks such that organics toxicity appears unlikely. The ammonia concentration (3 mg/L) is also consistent with an absence of toxicity.

Of note was the occurrence of HMX in the sediment that was not detected at any of the other sampling locations. Although the concentration (1,916 µg/kg) is not expected to be acutely toxic to aquatic organisms (Todd Bridges, USACE, WES; personal communication), chronic effects (i.e., 10-day exposures) thresholds are unknown and could be more sensitive. Also, as noted for nitrobenzene at Station 2, the presence of this chemical may indicate unusual properties of the water or associated particulates that could contribute to a toxic effect in the bulk sediment.

Un-tested Stations (3, 4, 7, 9, 14). To complete the evaluation of available data from Areas 39/41 and 42, chemistry results for stations that were not included in the TIE were examined. In the following paragraphs, these data are evaluated in the context of the TIE study.

Stations 3, 4 and 7. In Area 39/41, intertidal beach Stations 3 and 4, and subtidal Station 7 were located upstream on the opposite side of the channel near Station 6. Bulk sediment survival for these three locations was 33%, 29%, and 20% respectively. Observed chemistry results from the sediment samples indicated that only beta-BHC (HQ = 298, Station 4) and total PCBs (HQ = 1.3, Station 7) exceeded sediment benchmarks (Table 3.1-1). Pore water elevations were also noted for beta-BHC and delta-BHC at Station 3 (HQ = 1.1). Hence, it is possible that these chemicals, particularly beta-BHC, could have contributed to the observed sediment toxicity. At present, the available TIE procedures (i.e. C_{18} treatment) do not appear to address the more polar pesticides such as beta-BHC.

Stations 9 and 14. Bulk sediment survival at Stations 9 and 14 in Area 42 was 33% and 18%, respectively. Station 9 had relatively high zinc (265 µg/kg) but this concentration was still below UET and marine PEL benchmarks. Measured SEM-AVS was highly positive (784 µm) and almost all due to zinc. However, the SEM zinc value appears anomalous as it exceeds the bulk sediment concentration. If real, this may reflect a non-homogeneous sample and thus the aliquot of sediment used for the bulk sediment may have been similarly enriched in zinc. Hence toxicity at this station could likely

be due to zinc. For Station 14, only one sediment benchmark was exceeded (Total PCBs, HQ = 1.5) although silver was near the sediment threshold (HQ = 0.9). Hence, substantial toxicity in pore water would not be expected, but these chemicals, particularly silver could have contributed to the observed bulk sediment toxicity.

4. SUMMARY AND CONCLUSIONS

In summary, TIE testing of pore water was performed in an attempt to determine sources of chemical toxicity observed in bulk sediment exposures. Samples were collected in two primary areas (Site 42 and Site 39/41) in order to capture a variety of contaminants and exposure conditions. Samples collected at Site 42 were focused on silver as the potential source of toxicity. All 15 of the stations were toxic to *Hyalella* in bulk sediments. There was considerable variability in TIE responses and in chemical measurements amongst the fifteen sampled sediments. The following are principal findings of the TIE study.

- The extent of toxicity observed in pore water was generally less than observed in the bulk sediment; only 6 of 10 samples exhibited toxicity in pore water exposures to *Hyalella* and *Pimephales*. Responses of the two species to the various treatments were in excellent agreement.
- Sample filtration resulted in partial toxicity removal at Stations 6 and 11, suggesting toxicity associated with the particulate fraction of the sample.
- C_{18} treatment for organics removal did not generally reduce toxicity, indicating PAHs, PCBs and most pesticides (with the possible exception of beta-BHC) were not responsible for the observed toxicity.
- Sodium thiosulfate additions that would bind certain metals including silver did not appear to moderate observed toxicity at Site 42 stations such that it is unlikely that silver contributed significantly to toxic effects in pore water. Area 39/41 Station 2 toxicity reduction with this treatment was observed at the lowest dilution (10%) and matching sediment and pore water data support a potential role of silver toxicity at this location.
- EDTA reduction on toxicity was expressed in samples from Stations 6, 11, and 15. Corresponding chemistry results are consistent with toxicity primarily associated with manganese (Stations 6 and 11) and zinc (Station 15).
- Zeolite and associated pH adjustment implicate ammonia as a principal source of toxicity at Stations 2 and 8.
- The TIE treatments generally removed toxicity in all but one location (Station 2). Toxicity at this location is possibly confounded by water hardness, exotics (explosives), and unusual organic carbon ratios in the pore water.

In general, there was good agreement between sediment and pore water test results; only four of ten TIE samples were found to be toxic in bulk sediment but not in pore water (Stations 1, 5, 10, 12). This could be due to:

- Non-contaminant factors such as grain size (e.g., Station 1, 94% sand),
- Sulfides in bulk sediment pore water (Station 10 = 44.6 mg/L sulfides) may exceed the tolerance limit of the species during sediment exposures,
- Differences in exposure durations causing significant toxicity in bulk sediment but only partial mortality in pore water (e.g., Station 5; bulk sediment = 41% survival, 100% pore water = 87% survival).
- The TIE did not address all potential sources of ecological stress related to novel sediment properties (e.g., Station 12, high sediment HMX increasing viscosity, or "stickiness") that a pore water test cannot detect.
- It may also be important to resolve whether the toxicity observed with the Station 2 sediment is associated with pesticides. This can be accomplished in a Phase II TIE with an elution column that specifically targets organochlorine pesticides, and/or employing a solid phase extraction medium that is expected to more efficiently remove the more polar organic compounds.

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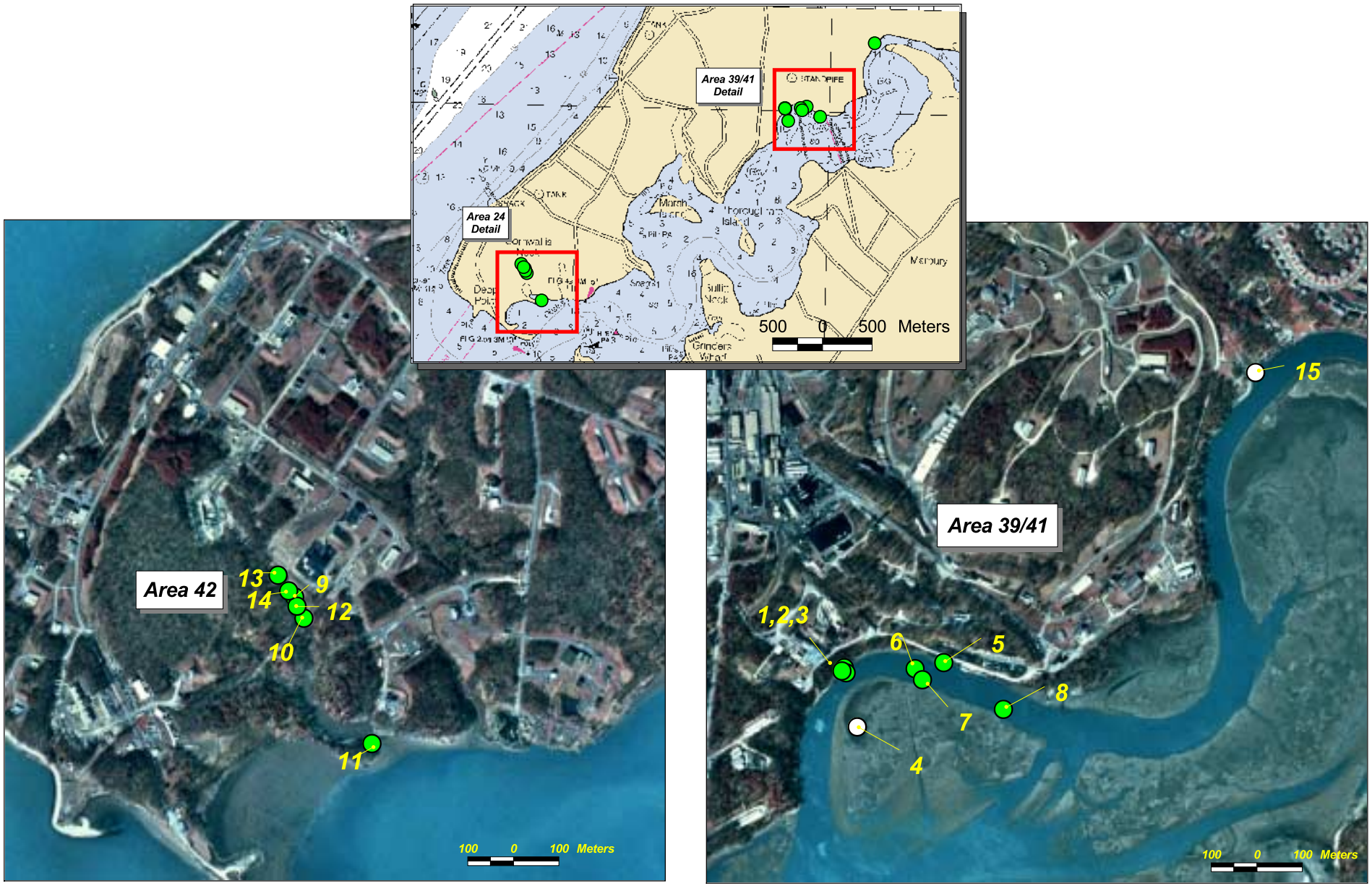

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Figure 2.0-1. Stations selected for the Indian Head Toxicity Identification Evaluation (TIE) demonstration.

2000 0 2000 4000 Feet

Legend
- Original Stations
- Relocated Stations

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B.D. Andrews, SAIC, 5 OCT 01

Figure 2.2-1. TIE pore water chemical fractionation procedure.

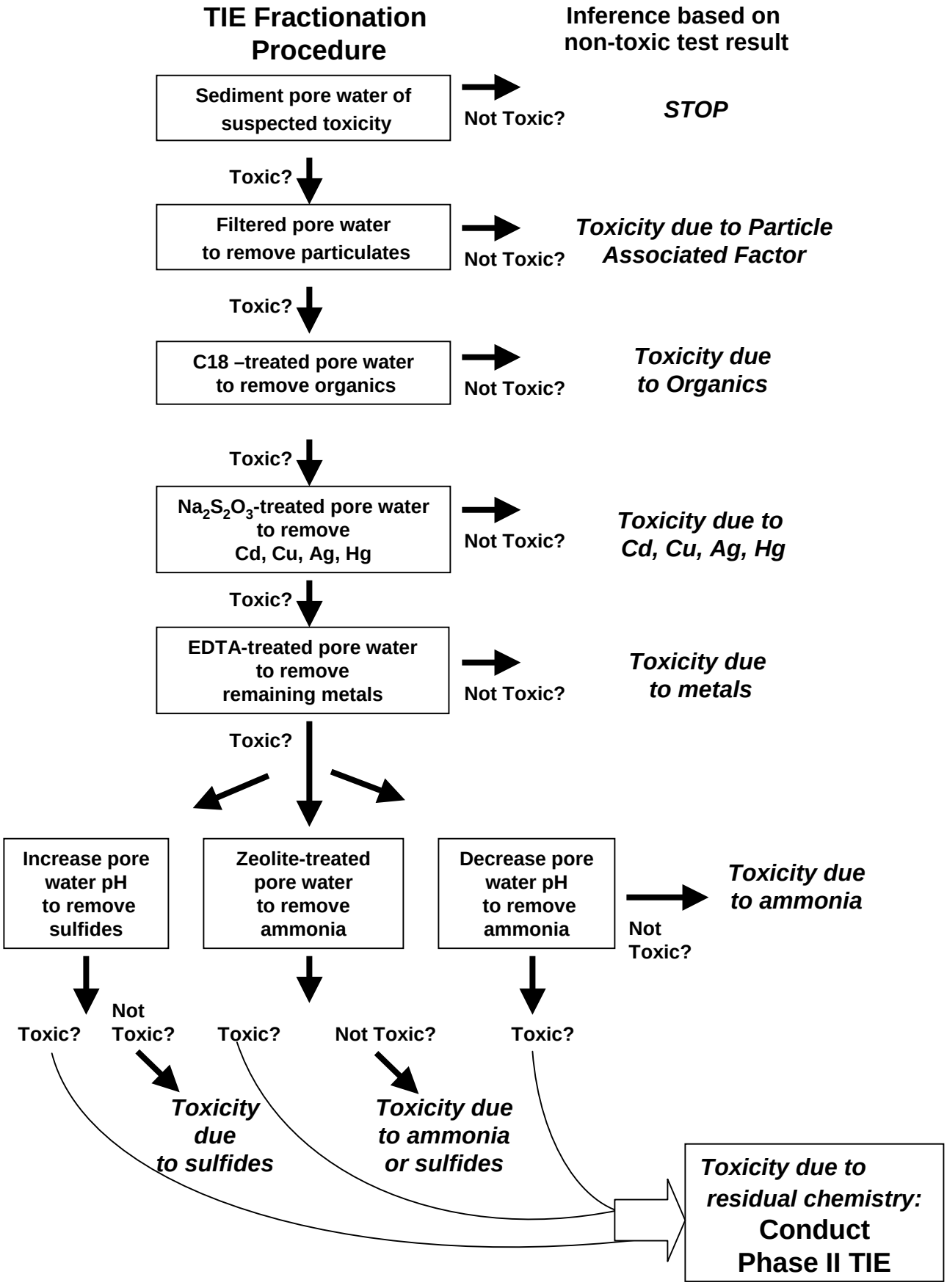


Table 2.1-1. Selection of benchmarks used in calculating sediment Hazard Quotients for the Indian Head TIE investigation.

		Freshwater	Marine		Selected[1]	
Class	Analyte	(UET)	BM	Source	BM	Source
MET	Aluminum, total					
MET	Arsenic	17	70	ER-M	17	UET
MET	Cadmium	3.0	9.6	ER-M	3.0	UET
MET	Chromium	95	370	ER-M	95	UET
MET	Copper	86	270	ER-M	86	UET
MET	Iron					
MET	Lead	127	218	ER-M	127	UET
MET	Manganese	1100			1000	UET
MET	Nickel	43	52	ER-M	43	UET
MET	Silver	4.5	3.7	ER-M	4.5	UET
MET	Zinc	520	410	ER-M	520	UET
MET	SEM-AVS		5.0	EPA	5	EPA
PAH	1-Methylnaphthalene					
PAH	1-Methylphenanthrene					
PAH	2,3,5 Trimethylnaphthalene					
PAH	2,6 Dimethylnaphthalene					
PAH	2-Methylnaphthalene		670	ER-M	670	ER-M
PAH	Acenaphthene	290	500	ER-M	290	UET
PAH	Acenaphthylene	160	640	ER-M	160	UET
PAH	Anthracene	260	1100	ER-M	260	UET
PAH	Benzo(a)anthracene	500	1600	ER-M	500	UET
PAH	Benzo[a]pyrene	700	1600	ER-M	700	UET
PAH	Benzo[b]fluoranthene		9900	AET-H	9900	AET-H
PAH	Benzo[e]pyrene					
PAH	Benzo[ghi]perylene	300	2600	AET-H	300	UET
PAH	Benzo[k]fluoranthene	13400	9900	AET-H	13400	UET
PAH	Biphenyl		110000	SQAL	110000	SQAL
PAH	Chrysene	800	2800	ER-M	800	UET
PAH	Dibenzothiophene					
PAH	Dibenz[a,h]anthracene	100	260	ER-M	100	UET
PAH	Fluoranthene	1500	5100	ER-M	1500	UET
PAH	Fluorene	300	540	ER-M	300	UET
PAH	Indeno[1,2,3-cd]pyrene	330	2600	AET-L	330	UET
PAH	Naphthalene	600	2100	ER-M	600	UET
PAH	Perylene					
PAH	Phenanthrene	800	1500	ER-M	800	UET
PAH	Pyrene	1000	2600	ER-M	1000	UET
PAH	Total LMW (L) PAHs	5300	3160	ER-M	5300	UET
PAH	Total HMW (H) PAHs	6500	9600	ER-M	6500	UET
PAH	Total LMW+HMW PAHs	12000	44792	ER-M	12000	UET
PCB	Total (Sumx2) PCBs	26	180	ER-M	26	UET
PST	2,4'-DDD		27	ER-M	27	ER-M
PST	2,4'-DDE		27	ER-M	27	ER-M
PST	2,4'-DDT		27	ER-M	27	ER-M
PST	4,4'-DDD	60	27	ER-M	60	UET
PST	4,4'-DDE	50	27	ER-M	50	UET
PST	4,4'-DDT	50	27	ER-M	50	UET
PST	Aldrin	40			40	UET
PST	alpha-BHC		1.0	PEL	1.0	PEL
PST	alpha-Chlordane		4.8	PEL	4.8	PEL
PST	beta-BHC		1.0	PEL	1.0	PEL
PST	delta-BHC		1.0	PEL	1.0	PEL
PST	Dieldrin	300	4.3	PEL	300	UET
PST	Endosulfan I		290	SQAL	290	SQAL
PST	Endosulfan II		140	SQAL	140	SQAL
PST	Endosulfan sulfate					
PST	Endrin	500	420	SQAL	500	UET
PST	Endrin aldehyde					
PST	Endrin ketone					
PST	gamma-BHC	9	1	PEL	9	UET
PST	gamma-Chlordane		4.8	PEL	4.8	PEL
PST	Heptachlor	10			10	UET
PST	Heptachlor epoxide	30			30	UET
PST	Hexachlorobenzene	100	230	AET-H	100	UET
PST	Methoxychlor		190	SQAL	190	SQAL
PST	Mirex	800			800	UET
PST	Toxaphene					

1- Benchmarks were selected in the following order of priority:

1) Freshwater Sediment UET; 2) Marine Sediment: a) ER-M; b) PEL; 3) AET-H; c) SQAL; d) EPA.

Units: Metals= mg/g; PCBs, Pesticides (PST), PAHs, Explosives (EXP) = ng/g; AVS, SEM=µM/g.

LMW PAH = sum of 7 2-ring & 3-ring PAHs included in NOAA ER-L/ER-M benchmarks (Long et al. 1995); (methylnaphthalene, acenaphthene, acenaphthylene, anthracene, fluorene, naphthalene, phenanthrene).

HMW PAH = sum of 6 4-ring and 5-ring PAHs included in NOAA ER-L/ER-M benchmarks (Long et al. 1995); (benzo(a)anthracene, benzo(a)pyrene, chrysene, dibenz(a,h)anthracene, fluoranthene, pyrene).

Total PAHs - sum of LMW & HMW PAHs; Total PCBs - Sum of individual PCB congeners x 2.

UET = Upper Effects Threshold (NOAA 1997).

ER-L/M = NOAA Effects Range-Low/Median (Long et al. 1995 in U.S. EPA 1997).

TEL/PEL = Threshold Effects Levels/Probable Effects Levels (FDEP 1994 in U.S. EPA 1997).

AET-L/H = Apparent Effects Threshold Low/High; normalized to dry weight (Barrick et al. 1988 in U.S. EPA 1997).

SQAL = EPA Sediment Quality Advisory Levels, based on 1% TOC (U.S. EPA 1997).

EPA = EPA SEM-AVS water quality screening value, uM/g dry weight (U.S. EPA 1997).

Table 2.1-2. Selection of benchmarks used in calculating pore water Hazard Quotients for the Indian Head TIE investigation.

		Water Quality Criteria		Selected Sediment[2]			Estimated	Selected Pore water[1]	
Class	Analyte	WQC-FA	WQC-SA	BM	Source	Koc	Pore water	BM	Source
MET	Aluminum, total	750						750	WQC-FA
MET	Arsenic	360		17	UET			360	WQC-FA
MET	Cadmium	3.9		3.0	UET			3.9	WQC-FA
MET	Chromium	16		95	UET			16	WQC-FA
MET	Copper	18		86	UET			18	WQC-FA
MET	Iron								
MET	Lead	83		127	UET			83	WQC-FA
MET	Manganese	1000		1000	UET			1000	WQC-FA
MET	Nickel	1400		43	UET			1400	WQC-FA
MET	Silver	4.1		4.5	UET			4.1	WQC-FA
MET	Zinc	120		520	UET			120	WQC-FA
MET	SEM-AVS			5	EPA				
PAH	1-Methylnaphthalene					8.0E+3			
PAH	1-Methylphenanthrene					9.9E+4			
PAH	2,3,5 Trimethylnaphthalene								
PAH	2,6 Dimethylnaphthalene					3.4E+4			
PAH	2-Methylnaphthalene		300	670	ER-M	8.0E+3	8.4	300	WQC-SA
PAH	Acenaphthene	1700		290	UET	7.1E+3	4.1	1700	WQC-FA
PAH	Acenaphthylene		300	160	UET	9.6E+3	1.7	300	WQC-SA
PAH	Anthracene		300	260	UET	3.0E+4	0.9	300	WQC-SA
PAH	Benzo(a)anthracene		300	500	UET	4.0E+5	0.1	300	WQC-SA
PAH	Benzo[a]pyrene		300	700	UET	1.0E+6	6.9E-2	300	WQC-SA
PAH	Benzo[b]fluoranthene		300	9900	AET-H	1.2E+6	0.8	300	WQC-SA
PAH	Benzo[e]pyrene					1.0E+6			
PAH	Benzo[ghi]perylene		300	300	UET	3.9E+6	7.8E-3	300	WQC-SA
PAH	Benzo[k]fluoranthene			13400	UET	1.2E+6	1.1	1.1	estimated
PAH	Biphenyl			110000	SQAL	7.8E+3	1407	1407	estimated
PAH	Chrysene		300	800	UET	4.0E+5	0.2	300	WQC-SA
PAH	Dibenzothiophene								
PAH	Dibenz[a,h]anthracene		300	100	UET	3.8E+6	2.7E-3	300	WQC-SA
PAH	Fluoranthene	3980		1500	UET	1.1E+5	1.4	3980	WQC-FA
PAH	Fluorene		300	300	UET	1.4E+4	2.2	300	WQC-SA
PAH	Indeno[1,2,3-cd]pyrene		300	330	UET	3.4E+6	9.6E-3	300	WQC-SA
PAH	Naphthalene	2300		600	UET	2.0E+3	30	2300	WQC-FA
PAH	Perylene					8.9E+5			
PAH	Phenanthrene	30		800	UET	3.0E+4	2.7	30	WQC-FA
PAH	Pyrene		300	1000	UET	1.1E+5	0.9	300	WQC-SA
PAH	Total LMW (L) PAHs		300	5300	UET			300	WQC-SA
PAH	Total HMW (H) PAHs		300	6500	UET			300	WQC-SA
PAH	Total LMW+HMW PAHs		300	12000	UET	7.6E+4	16	300	WQC-SA
PCB	Total (Sumx2) PCBs	2		26	UET	2.7E+6	9.7E-4	2.0	WQC-FA
PST	2,4'-DDD			27	ER-M	9.9E+5	2.7E-3	2.7E-3	estimated
PST	2,4'-DDE			27	ER-M	4.4E+6	6.1E-4	6.1E-4	estimated
PST	2,4'-DDT			27	ER-M	4.4E+6	6.1E-4	6.1E-4	estimated
PST	4,4'-DDD	0.6		60	UET	9.9E+5	6.0E-3	0.6	WQC-FA
PST	4,4'-DDE	1050		50	UET	4.4E+6	1.1E-3	1050	WQC-FA
PST	4,4'-DDT	1.1		50	UET	4.4E+6	1.1E-3	1.1	WQC-FA
PST	Aldrin	3.0		40	UET	2.5E+6	1.6E-3	3.0	WQC-FA
PST	alpha-BHC			1.0	PEL	5.4E+3	1.8E-2	1.8E-2	estimated
PST	alpha-Chlordane			4.8	PEL	2.5E+6	2.0E-4	2.0E-4	estimated
PST	beta-BHC			1.0	PEL	5.6E+3	1.8E-2	1.8E-2	estimated
PST	delta-BHC			1.0	PEL	5.5E+3	1.8E-2	1.8E-2	estimated
PST	Dieldrin	2.5		300	UET	1.9E+5	0.2	2.5	WQC-FA
PST	Endosulfan I	0.2		290	SQAL			0.2	WQC-FA
PST	Endosulfan II			140	SQAL	1.1E+4	1.3	1.3	estimated
PST	Endosulfan sulfate								
PST	Endrin	0.2		500	UET	9.4E+4	0.5	0.2	WQC-FA
PST	Endrin aldehyde								
PST	Endrin ketone								
PST	gamma-BHC	2.0	0.2	9	UET	4.6E+3	0.2	2.0	WQC-FA
PST	gamma-Chlordane			4.8	PEL	1.6E+6	2.9E-4	2.9E-4	estimated
PST	Heptachlor	0.5		10	UET	2.5E+6	4.1E-4	0.5	WQC-FA
PST	Heptachlor epoxide	0.5		30	UET	2.5E+6	1.2E-3	0.5	WQC-FA
PST	Hexachlorobenzene	6.0		100	UET	6.2E+5	1.6E-2	6.0	WQC-FA
PST	Methoxychlor			190	SQAL				
PST	Mirex			800	UET	5.9E+6	1.3E-2	1.3E-2	estimated
PST	Toxaphene	7.3E-2						7.3E-2	WQC-FA

Class	Analyte	Water Quality Criteria		Selected Sediment[2]		Koc	Estimated Pore water	Selected Pore water[1]	
		WQC-FA	WQC-SA	BM	Source			BM	Source
EXP	1,3,5-Trinitrobenzene								
EXP	1,3-Dinitrobenzene								
EXP	2,4,6-Trinitrotoluene								
EXP	2,4-Dinitrotoluene	330						330	WQC-FA
EXP	2,6-Dinitrotoluene								
EXP	2-Amino-4,6-dinitrotoluene								
EXP	2-Nitrotoluene								
EXP	3-Nitrotoluene								
EXP	4-Amino-2,6-dinitrotoluene								
EXP	4-Nitrotoluene								
EXP	HMX								
EXP	Nitrobenzene	27000						27000	WQC-FA
EXP	RDX								
EXP	Tetryl								

1- Benchmarks (units = µg/l) were selected in the following order of priority:
1) WQC-FA; 2) WQC-SA; 3) Estimated.
WQC-FA = freshwater acute (NOAA 1997); WQC-SA = saltwater acute (NOAA 1997); Estimated = sed. BM/(Koc*0.01) .
2- See Table 2.2-1 for sediment benchmark selection process and definitions.
LMW PAH = sum of 7 2-ring & 3-ring PAHs included in NOAA ER-L/ER-M benchmarks (Long et al. 1995);
(methylnaphthalene, acenaphthene, acenaphthylene, anthracene, fluorene, naphthalene, phenanthrene).
HMW PAH = sum of 6 4-ring and 5-ring PAHs included in NOAA ER-L/ER-M benchmarks (Long et al. 1995);
(benzo(a)anthracene, benzo(a)pyrene, chrysene, dibenz(a,h)anthracene, fluoranthene, pyrene).
Total PAHs - sum of LMW & HMW PAHs; Total PCBs - Sum of individual PCB congeners x 2.

Table 2.3-1. Summary of the bulk sediment toxicity test procedures with *Hyalella azteca* employed in the Indian Head TIE investigation[a].

Test Duration	10 day
Number of Organisms per Chamber	20
Number of Replicates per Treatment	8
Test Chambers	800 mL glass jars
Test Temperature	23 ^{o}C
Salinity	0 ppt
Photoperiod	7-14 days
Volume of Sediment	175 mL
Volume of Overlying Water	625 mL
Type of Water	clean freshwater
Bay Feeding/Chamber	YCT
Endpoint	survival
Acceptance Criteria	85% survival in control

a U.S. EPA, 2000. Methods for Measuring the Toxicity and Bioaccumulation of Sediment-Associated Contaminants with Freshwater Invertebrates. Second Ed. EPA 600/R-99/064. EPA Office of Research and Development, Duluth, MN. March.

Table 2.3-2. Summary of test conditions for acute water-only toxicity tests with the freshwater fish, *Pimephales promelas*[a] and the freshwater amphipod, *Hyalella azteca*[b] measured during the Indian Head TIE study.

	P. promelas	*H. azteca*
Test type	Static non-renewal	Static non-renewal
Test Duration	72 hr	48 hr
Number of Replicates per Treatment	3	3
Number of Organisms per Chamber	5	5
Test Chambers	25 mL vial	25 mL vial
Test Temperature	25°C	23 °C
Test concentrations	4 (10, 25, 50, 100%)	4 (10, 25, 50, 100%)
Salinity	0 ppt	0 ppt
Photoperiod	16:8	16:8
Age/Size of Test Organisms	24 hr. old	7-14 days
Volume of Overlying Water	20 mL	20 mL
Type of Water	clean freshwater	clean freshwater
Bay Feeding/Chamber	none	none
Endpoint	survival	survival
Physical measurements[1]	Dissolved oxygen, pH ammonia, temperature	Dissolved oxygen, pH ammonia, temperature
Acceptance Criteria	80% survival in control	85% survival in control

a. U.S. EPA, 1991. Methods for aquatic toxicity identification evaluations: Phase I Toxicity Characterization Procedures. EPA-600/3-88-034. Environmental Research Laboratory, Duluth, MN.

b. U.S. EPA, 2000. Methods for Measuring the Toxicity and Bioaccumulation of Sediment-Associated Contaminants with Freshwater Invertebrates. Second Ed. EPA 600/R-99/064. EPA Office of Research and Development, Duluth, MN. March.

Table 2.3-3. Contaminants measured in sediments and pore waters for the Indian Head TIE demonstration program.

Analytes for Sediment Analyses	***Method***	***Description***	***Unit***	***MDL***	***Laboratory RL***
INORGANICS					
TOC	SW9060	Combustion	mg/kg	547	6000
METALS					
Aluminum	SW3050B/6010B	ICP	mg/kg	3.7	20.0
Antimony	SW3050B/6010B	ICP - Trace	mg/kg	0.22	0.60
Arsenic	SW3050B/6010B	ICP - Trace	mg/kg	0.093	1.0
Cadmium	SW3050B/6010B	ICP - Trace	mg/kg	0.022	0.50
Chromium	SW3050B/6010B	ICP - Trace	mg/kg	0.091	1.0
Copper	SW3050B/6010B	ICP - Trace	mg/kg	0.17	1.0
Lead	SW3050B/6010B	ICP - Trace	mg/kg	0.093	0.30
Iron	SW3050B/6010B	ICP	mg/kg	3.1	10.0
Nickel	SW3050B/6010B	ICP - Trace	mg/kg	0.25	1.0
Silver	SW3050B/6010B	ICP - Trace	mg/kg	0.28	1.0
Zinc	SW3050B/6010B	ICP	mg/kg	0.79	2.0
Mercury	SW7471A	Cold Vapor	mg/kg	0.027	0.10
PESTICIDES					
Aldrin	SW3540C/8081A	GC/ECD	ug/kg	0.52	1.7
a-Chlordane	SW3540C/8081A	GC/ECD	ug/kg	0.70	1.7
g-Chlordane	SW3540C/8081A	GC/ECD	ug/kg	0.35	1.7
4,4'-DDD	SW3540C/8081A	GC/ECD	ug/kg	0.42	3.3
4,4'-DDE	SW3540C/8081A	GC/ECD	ug/kg	0.40	3.3
4,4'-DDT	SW3540C/8081A	GC/ECD	ug/kg	0.66	3.3
Dieldrin	SW3540C/8081A	GC/ECD	ug/kg	0.43	3.3
Endosulfan I	SW3540C/8081A	GC/ECD	ug/kg	0.72	1.7
Endosulfan II	SW3540C/8081A	GC/ECD	ug/kg	0.36	3.3
Endrin aldehyde	SW3540C/8081A	GC/ECD	ug/kg	0.94	3.3
Heptachlor	SW3540C/8081A	GC/ECD	ug/kg	0.60	1.7
Heptachlor epoxide	SW3540C/8081A	GC/ECD	ug/kg	0.81	1.7
Hexachlorobenzene	SW3540C/8081A	GC/ECD	ug/kg	0.84	3.3
Alpha-Hexacyclochlorohexane	SW3540C/8081A	GC/ECD	ug/kg	TBD	1.7
Beta-Hexacyclochlorohexane	SW3540C/8081A	GC/ECD	ug/kg	TBD	1.7
Mirex	SW3540C/8081A	GC/ECD	ug/kg	TBD	3.3
Toxaphene	SW3540C/8081A	GC/ECD	ug/kg	14	170
PCB CONGENERS					
2,4'-dichlorobiphenyl (BZ # 8)	SW3540C/8082	GC/ECD	ug/kg	0.10	1.0
2,2',5-trichlorobiphenyl (BZ # 18)	SW3540C/8082	GC/ECD	ug/kg	0.10	1.0
2,4,4'-trichlorobiphenyl (BZ # 28)	SW3540C/8082	GC/ECD	ug/kg	0.037	1.0
2,2',3,5'-tetrachlorobiphenyl (BZ # 44)	SW3540C/8082	GC/ECD	ug/kg	0.11	1.0
2,2',5,5'-tetrachlorobiphenyl (BZ # 52)	SW3540C/8082	GC/ECD	ug/kg	0.10	1.0
2,3',4,4'-tetrachlorobiphenyl (BZ # 66)	SW3540C/8082	GC/ECD	ug/kg	0.056	1.0
3,3',4,4'-tetrachlorobiphenyl (BZ # 77)	SW3540C/8082	GC/ECD	ug/kg	0.082	1.0
2,2',4,5,5'-pentachlorobiphenyl (BZ # 101)	SW3540C/8082	GC/ECD	ug/kg	0.058	1.0
2,3,3',4,4'-pentachlorobiphenyl (BZ # 105)	SW3540C/8082	GC/ECD	ug/kg	0.18	1.0
2,3',4,4',5-pentachlorobiphenyl (BZ # 118)	SW3540C/8082	GC/ECD	ug/kg	0.069	1.0
3,3',4,4',5-pentachlorobiphenyl (BZ # 126)	SW3540C/8082	GC/ECD	ug/kg	0.049	1.0
2,2',3,3',4,4'-hexachlorobiphenyl (BZ # 128)	SW3540C/8082	GC/ECD	ug/kg	0.048	1.0
2,2',3,4,4',5'-hexachlorobiphenyl (BZ # 138)	SW3540C/8082	GC/ECD	ug/kg	0.043	1.0
2,2',4,4',5,5'-hexachlorobiphenyl (BZ # 153)	SW3540C/8082	GC/ECD	ug/kg	0.037	1.0
2,2',3,3',4,4',5-heptachlorobiphenyl (BZ # 170)	SW3540C/8082	GC/ECD	ug/kg	0.071	1.0

2,2',3,4,4',5,5'-heptachlorobiphenyl (BZ # 180)	SW3540C/8082	GC/ECD	ug/kg	0.087	1.0
2,2',3,4',5,5',6-heptachlorobiphenyl (BZ # 187)	SW3540C/8082	GC/ECD	ug/kg	0.060	1.0
2,2',3,3',4,4',5,6-octachlorobiphenyl (BZ # 195)	SW3540C/8082	GC/ECD	ug/kg	0.087	1.0
2,2',3,3',4,4',5,5',6-nonachlorobiphenyl (BZ # 206)	SW3540C/8082	GC/ECD	ug/kg	0.13	1.0
2,2',3,3',4,4',5,5',6,6'-decachlorobiphenyl (BZ # 209)	SW3540C/8082	GC/ECD	ug/kg	0.16	1.0
SVOCs					
Acenaphthene	SW3540C/8270C -Low	GC/MS	ug/kg	0.6	2
Acenaphthylene	SW3540C/8270C -Low	GC/MS	ug/kg	0.67	2
Anthracene	SW3540C/8270C -Low	GC/MS	ug/kg	0.67	2
Benzo[a]anthracene	SW3540C/8270C -Low	GC/MS	ug/kg	0.76	2
Benzo[b]fluoranthene	SW3540C/8270C -Low	GC/MS	ug/kg	1.5	2
Benzo[k]fluoranthene	SW3540C/8270C -Low	GC/MS	ug/kg	0.85	2
Benzo[a]pyrene	SW3540C/8270C -Low	GC/MS	ug/kg	0.86	2
Benzo(e)pyrene	SW3540C/8270C -Low	GC/MS	ug/kg	1.11	2
Benzo[ghi]perylene	SW3540C/8270C -Low	GC/MS	ug/kg	1.71	2
Biphenyl	SW3540C/8270C -Low	GC/MS	ug/kg	0.9	2
Chrysene	SW3540C/8270C -Low	GC/MS	ug/kg	0.6	2
Dibenzo[a,h]anthracene	SW3540C/8270C -Low	GC/MS	ug/kg	1.86	2
Fluoranthene	SW3540C/8270C -Low	GC/MS	ug/kg	0.46	2
Fluorene	SW3540C/8270C -Low	GC/MS	ug/kg	0.42	2
Indeno[1,2,3-cd]pyrene	SW3540C/8270C -Low	GC/MS	ug/kg	1.78	2
2-Methylnaphthalene	SW3540C/8270C -Low	GC/MS	ug/kg	0.4	2
2,6-Dimethylnaphthalene	SW3540C/8270C -Low	GC/MS	ug/kg	0.99	2
2,3,5-Trimethylnaphthalene	SW3540C/8270C -Low	GC/MS	ug/kg	1.14	2
Naphthalene	SW3540C/8270C -Low	GC/MS	ug/kg	0.22	2
1-Methylphenanthrene	SW3540C/8270C -Low	GC/MS	ug/kg	0.42	2
Phenanthrene	SW3540C/8270C -Low	GC/MS	ug/kg	0.47	2
Perylene	SW3540C/8270C -Low	GC/MS	ug/kg	1.13	2
Pyrene	SW3540C/8270C -Low	GC/MS	ug/kg	0.42	2
1-Methylnaphthalene	SW3540C/8270C -Low	GC/MS	ug/kg	0.61	2
EXPLOSIVES					
HMX	SW8330	HPLC	ug/kg	190	500
RDX	SW8330	HPLC	ug/kg	180	500
135TNB	SW8330	HPLC	ug/kg	83	250
13DNB	SW8330	HPLC	ug/kg	73	250
NB	SW8330	HPLC	ug/kg	110	250
TETRYL	SW8330	HPLC	ug/kg	240	750
246TNT	SW8330	HPLC	ug/kg	180	500
2amDNT	SW8330	HPLC	ug/kg	140	500
4amDNT	SW8330	HPLC	ug/kg	220	500
24DNT	SW8330	HPLC	ug/kg	86	250
26DNT	SW8330	HPLC	ug/kg	200	500
2NT	SW8330	HPLC	ug/kg	150	500
3NT	SW8330	HPLC	ug/kg	230	500
4NT	SW8330	HPLC	ug/kg	120	500
Pentaerythritol tetranitrate (PETN)	SW8330	HPLC	ug/kg	660	2000
Nitroglycerin	SW8330	HPLC	ug/kg	240	1000
SEM					
Cadmium	US EPA 1992/6010B	ICP/AES	umol/g	0.002	0.1
Copper	US EPA 1992/6010B	ICP/AES	umol/g	0.005	0.1
Lead	US EPA 1992/6010B	ICP/AES	umol/g	0.015	0.1
Nickel	US EPA 1992/6010B	ICP/AES	umol/g	0.045	0.1
Silver	US EPA 1992/6010B	ICP/AES	umol/g	TBD	TBD
Zinc	US EPA 1992/6010B	ICP/AES	umol/g	0.030	0.1
Acid Volatile Sulfides	US EPA 1992/6010B	ICP/AES	umol/g	0.075	0.1

Analytes for Pore Water Analyses-Fresh					
Cadmium	6020	ICP/MS	µg/L	0.19	2.0
Copper	6020	ICP/MS	µg/L	1.4	2.0
Lead	6020	ICP/MS	µg/L	0.22	2.0
Nickel	6020	ICP/MS	µg/L	1.1	2.0
Silver	6020	ICP/MS	µg/L	0.15	2.0
Zinc	6020	ICP/MS	µg/L	4.0	10.0
Arsenic	6020	ICP/MS	µg/L	0.24	2.0
Iron	6020	ICP/MS	µg/L	85	200
Aluminum	6020	ICP/MS	µg/L	17	20
TOC	SW9060	Combustion	mg/L	0.19	1.0
Sulfide	SW9034	Titration	mg/L	0.25	1.0

Table 3.1-1. Summary of Hazard Quotients calculated from sediment concentrations measured in the Indian Head TIE study[1].

Class	Analyte	Benchmark Source[2]	IH-01	IH-02	IH-03	IH-04	IH-05	IH-06	IH-07	IH-08	IH-09	IH-10	IH-11	IH-12	IH-13	IH-14	IH-15
MET	Aluminum, total	NA															
MET	Arsenic	UET	-	-	-	-	-	-	-	-	-	-	-	-	-	-	++
MET	Cadmium	UET	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+++
MET	Chromium	UET	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MET	Copper	UET	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+
MET	Iron	NA															
MET	Lead	UET	-	-	-	-	-	-	-	-	-	-	-	-	-	-	++
MET	Manganese	UET	-	-	-	+	-	+	-	+	-	-	-	-	-	-	-
MET	Nickel	UET	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MET	Silver	UET	+	+++	-	-	-	-	-	-	+	++	-	++	+	-	-
MET	Zinc	UET	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+++
MET	SEM-AVS	EPA	-	-	-	-	-	-	-	-	+++	-	-	-	-	-	+++
PAH	1-Methylnaphthalene	NA															
PAH	1-Methylphenanthrene	NA															
PAH	2,3,5 Trimethylnaphthalene	NA															
PAH	2,6 Dimethylnaphthalene	NA															
PAH	2-Methylnaphthalene	ER-M	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PAH	Acenaphthene	UET	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PAH	Acenaphthylene	UET	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PAH	Anthracene	UET	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-
PAH	Benzo(a)anthracene	UET	-	-	-	-	+	-	-	-	-	-	-	-	+	-	-
PAH	Benzo[a]pyrene	UET	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-
PAH	Benzo[b]fluoranthene	AET-H	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PAH	Benzo[e]pyrene	NA															
PAH	Benzo[ghi]perylene	UET	-	-	-	-	-	-	-	-	-	-	-	-	++	-	-
PAH	Benzo[k]fluoranthene	UET	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PAH	Biphenyl	SQAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PAH	Chrysene	UET	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-
PAH	Dibenzothiophene	NA															
PAH	Dibenz[a,h]anthracene	UET	-	-	-	-	+	-	-	-	-	-	-	-	++	-	-
PAH	Fluoranthene	UET	-	-	-	-	+	-	-	-	-	-	-	-	+	-	-
PAH	Fluorene	UET	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PAH	Indeno[1,2,3-cd]pyrene	UET	-	-	-	-	+	-	-	-	-	-	-	-	++	-	-
PAH	Naphthalene	UET	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PAH	Perylene	NA															
PAH	Phenanthrene	UET	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PAH	Pyrene	UET	-	-	-	-	+	-	-	-	-	-	-	-	+	-	-
PAH	Total LMW (L) PAHs	UET	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PAH	Total HMW (H) PAHs	UET	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-
PAH	Total LMW+HMW PAHs	UET	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PCB	Total (Sumx2) PCBs	UET	-	++	-	-	+	+	+	-	+	++	-	++	+++	+	-
PST	2,4'-DDD	ER-M	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-
PST	2,4'-DDE	ER-M	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PST	2,4'-DDT	ER-M	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PST	4,4'-DDD	UET	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PST	4,4'-DDE	UET	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PST	4,4'-DDT	UET	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PST	Aldrin	UET	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PST	alpha-BHC	PEL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PST	alpha-Chlordane	PEL	-	++	-	-	-	-	-	-	-	-	-	-	-	-	-
PST	beta-BHC	PEL	+	+++	-	+++	-	+++	++	-	+	+	-	-	+	-	-
PST	delta-BHC	PEL	-	-	-	+	-	+	-	-	+	-	-	-	-	-	-
PST	Dieldrin	UET	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PST	Endosulfan I	SQAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PST	Endosulfan II	SQAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PST	Endosulfan sulfate	NA															
PST	Endrin	UET	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PST	Endrin aldehyde	NA															
PST	Endrin ketone	NA															
PST	gamma-BHC	UET	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PST	gamma-Chlordane	PEL	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
PST	Heptachlor	UET	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PST	Heptachlor epoxide	UET	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PST	Hexachlorobenzene	UET	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PST	Methoxychlor	SQAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PST	Mirex	UET	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PST	Toxaphene	NA															

LMW PAH = sum of 7 2-ring & 3-ring PAHs included in NOAA ER-L/ER-M benchmarks (Long et al. 1995);
(methylnaphthalene, acenaphthene, acenaphthylene, anthracene, fluorene, naphthalene, phenanthrene).
HMW PAH = sum of 6 4-ring and 5-ring PAHs included in NOAA ER-L/ER-M benchmarks (Long et al. 1995);
(benzo(a)anthracene, benzo(a)pyrene, chrysene, dibenz(a,h)anthracene, fluoranthene, pyrene).
Total PAHs - sum of LMW & HMW PAHs; Total PCBs - Sum of individual PCB congeners x 2.
1- Hazard Quotient (see Appendix A-2-2 for values) codes: <benchmark(BM) = "-"; >BM = "+"; >3xBM = "++"; >10xBM = "+++".
2- See Table 2.1-1 for benchmarks; NA = benchmark not available.

Table 3.1-2. Summary of Hazard Quotients calculated from pore water concentrations measured and predicted in the Indian Head TIE study[1].

Class	Analyte	Benchmark Source[2]	IH-01	IH-02	IH-03	IH-04	IH-05	IH-06	IH-07	IH-08	IH-09	IH-10	IH-11	IH-12	IH-13	IH-14	IH-15
MET	Aluminum, total	WQC-FA	++	-			-	-		-		-	-	+	-		+
MET	Arsenic	WQC-FA	-	-			-	-		-		-	-	-	-		-
MET	Cadmium	WQC-FA	-	-			-	-		-		-	-	-	-		+
MET	Chromium	WQC-FA	+	-			-	-		-		-	-	-	-		-
MET	Copper	WQC-FA	++	-			-	-		-		-	-	-	-		+
MET	Iron	NA															
MET	Lead	WQC-FA	+	-			-	-		-		-	-	-	-		+
MET	Manganese	WQC-FA	+	+			++	+++		+++		+	+++	++	++		-
MET	Nickel	WQC-FA	-	-			-	-		-		-	-	-	-		-
MET	Silver	WQC-FA	++	+++			-	-		+		-	+	+	-		-
MET	Zinc	WQC-FA	++	-			-	-		-		-	-	-	-		+++
MET	SEM-AVS	NA															
PAH	1-Methylnaphthalene	NA															
PAH	1-Methylphenanthrene	NA															
PAH	2,3,5 Trimethylnaphthalene	NA															
PAH	2,6 Dimethylnaphthalene	NA															
PAH	2-Methylnaphthalene	WQC-SA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PAH	Acenaphthene	WQC-FA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PAH	Acenaphthylene	WQC-SA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PAH	Anthracene	WQC-SA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PAH	Benzo(a)anthracene	WQC-SA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PAH	Benzo[a]pyrene	WQC-SA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PAH	Benzo[b]fluoranthene	WQC-SA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PAH	Benzo[e]pyrene	NA															
PAH	Benzo[ghi]perylene	WQC-SA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PAH	Benzo[k]fluoranthene	estimated	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PAH	Biphenyl	estimated	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PAH	Chrysene	WQC-SA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PAH	Dibenzothiophene	NA															
PAH	Dibenz[a,h]anthracene	WQC-SA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PAH	Fluoranthene	WQC-FA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PAH	Fluorene	WQC-SA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PAH	Indeno[1,2,3-cd]pyrene	WQC-SA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PAH	Naphthalene	WQC-FA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PAH	Perylene	NA															
PAH	Phenanthrene	WQC-FA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PAH	Pyrene	WQC-SA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PAH	Total LMW (L) PAHs	WQC-SA															
PAH	Total HMW (H) PAHs	WQC-SA															
PAH	Total LMW+HMW PAHs	WQC-SA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PCB	Total (Sumx2) PCBs	WQC-FA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PST	2,4'-DDD	estimated	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-
PST	2,4'-DDE	estimated	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PST	2,4'-DDT	estimated	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PST	4,4'-DDD	WQC-FA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PST	4,4'-DDE	WQC-FA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PST	4,4'-DDT	WQC-FA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PST	Aldrin	WQC-FA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PST	alpha-BHC	estimated	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-
PST	alpha-Chlordane	estimated	-	+++	-	-	-	-	-	-	-	-	-	-	-	-	-
PST	beta-BHC	estimated	++	+++	+	-	-	-	-	-	-	-	-	-	+	-	-
PST	delta-BHC	estimated	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-
PST	Dieldrin	WQC-FA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PST	Endosulfan I	WQC-FA															
PST	Endosulfan II	estimated	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PST	Endosulfan sulfate	NA															
PST	Endrin	WQC-FA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PST	Endrin aldehyde	NA															
PST	Endrin ketone	NA															
PST	gamma-BHC	WQC-FA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PST	gamma-Chlordane	estimated	-	++	-	-	-	-	-	-	-	-	-	-	-	-	-
PST	Heptachlor	WQC-FA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PST	Heptachlor epoxide	WQC-FA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PST	Hexachlorobenzene	WQC-FA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PST	Methoxychlor	NA															
PST	Mirex	estimated	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PST	Toxaphene	WQC-FA															
EXP	2,4-Dinitrotoluene	WQC-FA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
EXP	Nitrobenzene	WQC-FA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

LMW PAH = sum of 7 2-ring & 3-ring PAHs included in NOAA ER-L/ER-M benchmarks (Long et al. 1995);
(methylnaphthalene, acenaphthene, acenaphthylene, anthracene, fluorene, naphthalene, phenanthrene).
HMW PAH = sum of 6 4-ring and 5-ring PAHs included in NOAA ER-L/ER-M benchmarks (Long et al. 1995);
(benzo(a)anthracene, benzo(a)pyrene, chrysene, dibenz(a,h)anthracene, fluoranthene, pyrene).
Total PAHs - sum of LMW & HMW PAHs; Total PCBs - Sum of individual PCB congeners x 2.
1- Hazard Quotient (see Appendix A-2-2 for values) codes: <benchmark(BM) = "-"; >BM = "+"; >3xBM = "++"; >10xBM = "+++".
2- See Table 2.1-2 for benchmarks; NA = benchmark not available.

Table 3.2-1. Survival results from *Hyalella azteca* toxicity tests with Indian Head sediment and pore water samples.

Sample Identification	Percent Survival	
	Bulk Sediment Test Mean (SD)	Porewater Test Mean (CI)[1]
Lab Control	79(15)	100
IH-01	28(25) *	100
IH-02	53(16) *	0 *
IH-03	33(19) *	-
IH-04	29(24) *	-
IH-05	41(21) *	87 (13)
IH-06	54(16) *	27 (86) *
IH-07	20(19) *	-
IH-08	33(21) *	40 (132)
IH-09	33(31) *	
IH-10	1(4) *	93 (12)
IH-11	8(18) *	27 (43) *
IH-12	0(0) *	93 (12)
IH-13	24(19) *	66 (19) *
IH-14	18(22) *	
IH-15	0(0) *	0 *

* Statistically different (a = 0.05) compared to the Control data.

[1] CI = Confidence interval based on bootstrap analysis of replicate data.

Table 3.2-2. Summary of measured sediment and water quality parameters in samples selected for the Indian Head TIE evaluation.

	Sediment		Pore Water					Selected Ratios		
	TOC (%)	Total Ammonia-N; Overlying Water (mg/L)	TOC (mg/L)	DOC (mg/L)	Total Ammonia-N (mg/L)	Total Sulfide (mg/L)	Total Hardness (mg/L)	PW DOC/ PW TOC Ratio	PW TOC/ SED TOC Ratio	PW DOC/ SED TOC Ratio
Spike				7.7	140	n/a				
IH-1	0.54	< 0.10	19.8	17.2	2.0	<6.2	91.8	0.87	36.9	32.1
IH-2	0.51	< 0.10	62.8	47.0	2.8	<6.2	170	0.75	122	91.4
IH-5	12.6	< 0.10	27.2	11.7	25.0	<6.2	10.0	0.43	2.2	0.9
IH-6	18.1	1.0	33.3	23.8	37.5	<6.2	3.0	0.71	1.8	1.3
IH-8	14.6	2.7	28.3	20.2	35.0	<6.2	3.0	0.71	1.9	1.4
IH-10	11.8	< 0.10	37.7	11.6	6.0	44.6	17.0	0.31	3.2	1.0
IH-11	5.1	0.15	53.9	17.2	25.0	7.8	3.0	0.32	10.7	3.4
IH-12	5.9	< 0.10	37.6	15.4	3.0	6.6	136	0.41	6.4	2.6
IH-13	1.4	< 0.10	36.8	17.0	10.8	17.6	20.4	0.46	27.1	12.5
IH-15	1.7	< 0.10	20.3	9.9	0.75	<6.2	40.8	0.49	11.9	5.8
Median	5.5	1.0	35.1	17.2	8.4	12.7	18.7	0.47	8.5	3.0

Table 3.3-1. Summary of acute effects of spiked analytes on the Indian Head TIE test species.

A. Fluoranthene and silver effects on *Hyalella* and *Pimephales.*

	Hyalella LC_{50} (µg/L)	*Pimephales* LC_{50} (µg/L)
Fluoranthene	44 (Spehar et al., 1999)	7.7 (Genduza, 1990)
Silver	6.8 (Rodgers, 1990); < 4.4 (this study)	8.5 (Karen et al., 1999) 8.1 (this study)

B. pH effects on ammonia toxicity to *Hyalella* (LC values in mg/L)[1].

	Total Ammonia @ pH 7.2	Unionized Ammonia @ pH 7.2	Total Ammonia @ pH 8.9	Unionized Ammonia @ pH 8.9
LC_{20} (this study)	77.0 (33-92)	0.7 (0.34-0.76)	42.0 (38-42)	8 (7.0-8.0)
LC_{50} (this study)	101 (73-110)	0.8 (0.62-0.88)	52.5 (50-53)	11.5 (10.8-11.5)
LC_{50} (Besser et al., 1998)	126 (95-167) @ pH 7.5	1.8 (1.4-2.2) @ pH 7.5		

1 - Values for this study calculated by linear interpolation, with bootstrapped 95% confidence limit (Norber-King, 1988) using the ToxCalc version 5.0.23 (Tidepool Software).
Nominal concentrations for spiked sample were 200 ug/L fluoranthene and 500 ug/L silver; 140 mg/L ammonia was added after the EDTA step.

Table 3.3-2. Interpretive summary of *Hyalella azteca* LC_{20} toxicity values for Indian Head TIE samples.

Indian Head 'Area'; Station #	Untreated	Filtered	C_{18}	$Na_2S_2O_3$	EDTA	Zeolite		Post-EDTA Manipulations Low pH	Post-EDTA Manipulations High pH
39/41 IH-1	NT								
39/41 IH-2	+++	+++	+++	+++	+++	▽ ++		++	++
39/41 IH-5	NT								
39/41 IH- 6	++	++	▽ +	++/+[b]	▽ NT				
39/41 IH-8	++	++	++	++	++	▽		▽ NT	▽ +
39/41 IH- 15	+++	+++	+++	+++	▽ NT				
42 IH-10	NT								
42 IH-11	++	▽ +[a]	++	++	▽ NT				
42 IH-12	NT								
42 IH-13	+	▽ NT							

Toxicity Codes:
If LC20>80 then "NT" (not toxic)
If 40 < LC20 < 80 then "+" (slightly toxic)
If 10 < LC20 < 40 then "++" (moderately toxic)
If LC20 < 10 then "+++" (highly toxic)

Change in Toxicity:

If toxicity (no. of "+"s) reduces or increases by one category, then ▽ or △ respectively.

If toxicity (no. of "+"s) reduces or increases by > one category, then ▽ or △ respectively.

a- Rank based on estimated LC-20 because statistically significant toxicity was observed in one (50%) dilution
b- LC-20 at 38% borderline between categories

Table 3.3-3. Statistical summary of *Hyalella azteca* LC_{20} and LC_{50} toxicity values for Indian Head TIE samples.

A. LC_{20} values (with 95% confidence limit).

Indian Head 'Area'; Station #	UT	Filtered	C_{18}	$Na_2S_2O_3$	EDTA	Zeolite		Low pH	Hi pH
39/41 IH-2	<10	<10	<10	<10	<10	19.0 (6-42)		13.4 (6-38)	30.0 (26-30)
39/41 IH- 6	32.0 (20-89)	25.0 (9-82)	56.3 (0-71)	37.5 (29-85)	>100				
39/41 IH-8	21.3[1]	40.9[1]	31.5 (28-35)	30.6 (19-42)	30.9[1]	>100		>100	60.3 (14-66)
42 IH-11	20.2 (13-65)	43 (Est.)[1]	25.0 (0-60)	19.0 (0-147)	>100				
42 IH-13	72.5[1]	>100							
39/41 IH- 15	<10	<10	<10	<10	>100				
39/41 IH-1	>100								
39/41 IH- 5	>100								
42 IH-10	>100								
42 IH-12	>100								

1- Estimated LC-20 substituted because statistically significant toxicity was observed in the 50% dilution

B. LC_{50} values (with 95% confidence limit).

Indian Head 'Area'; Station #	UT	Filtered	C_{18}	$Na_2S_2O_3$	EDTA	Zeolite		Low pH	Hi pH
39/41 IH-2	<10	<10	<10	<10	<10	31.3 (2-44)		21.1 (12-49)	<10
39/41 IH- 6	50 (25-131)	54.7 (12-102)	84.4 (65-98)	58.3 (32-93)	>100				
39/41 IH-8	39.6[1]	96.7[1]	43.1[1]	43.1[1]	>100	>100		>100	76.8 (43-88)
42 IH-11	69.6 (44-87)	>100	91.71	>100	>100				
42 IH-13	>100	>100							
39/41 IH- 15	<10	<10	<10	<10	>100				
39/41 IH-1	>100	>100	>100	>100	>100	>100		X	>100
39/41 IH- 5	>100								
42 IH-10	>100								
42 IH-12	>100								

Note:
X: Not enough data availible
[1]: Tox-calc. Unable to calculate confidence limit.

Values calculated by linear interpolation, with bootstrapped 95% confidence limit (Norber-King,1988) using the ToxCalc version 5.0.23 (Tidepool Software).

Table 3.3-4. Statistical summary of *Pimephales promelas* LC_{20} and LC_{50} toxicity values for Indian Head TIE samples.

A. LC_{20} values (with 95% confidence limit).

Indian Head 'Area'; Station #	UT	Filtered	C_{18}	$Na_2S_2O_3$	EDTA
39/41 IH-2	<10	X	<10	<10	<10
39/41 IH- 6	31.3 (27-38)	60.0 (60-60)	29.4 (4-50)	35.0 (25-88)	60.0 (60-60)
39/41 IH-8	30.0 (30-30)	28.2 (23-32)	30.0 (30-30)	35.0 (25-88)	30.0 (30-30)
42 IH-11	60.0 (60-60)	X	57.1 (42-63)	57.1 (42-63)	57.1 (42-63)
42 IH-13	>100				
39/41 IH- 15	<10	<10	<10	<10	>100
39/41 IH-1	>100	>100			
39/41 IH- 5	60.0 (60-60)	60.0 (60-60)	60.0 (60-60)	>100	
42 IH-10	>100				
42 IH-12	>100				

B. LC_{50} values (with 95% confidence limit).

Indian Head 'Area'; Station #	UT	Filtered	C_{18}	$Na_2S_2O_3$	EDTA
39/41 IH-2	<10	X	<10	X	<10
39/41 IH- 6	42.5 (31-58)	75.0 (75-75)	49.3 (27-77)	50.0 (24-103)	75.0 (75-75)
39/41 IH-8	37.5 (37-37)	36.4 (33-39)	37.5 (38-38)	50.0 (24-103)	37.5 (38-38)
42 IH-11	75.0 (75-75)	X	73.2 (64-77)	73.2 (64-77)	73.2 (64-77)
42 IH-13	>100				
39/41 IH- 15	<10	<10	<10	<10	>100
39/41 IH-1	>100	>100			
39/41 IH- 5	75.0 (75-75)	75.0 (75-75)	75.0 (75-75)	>100	
42 IH-10	>100				
42 IH-12	>100				

Note:
X: Not enough data available.
[1]: Tox-calc. Unable to calculate confidence limit.
Values calculated by linear interpolation, with bootstrapped 95% confidence limit (Norber-King,1988) using the ToxCalc version 5.0.23 (Tidepool Software).

Table 3.3-5. Hazard Quotients for ammonia concentrations in Indian Head TIE pore waters.

Sample ID	Total Ammonia (mg/L)	pH	WQC-FA Benchmark @pH[1]	WQC-FA HQ	*Hyalella* Total Ammonia HQ[2]
Spike	140.00	7.76	8.70	16.10	3.33
IH-1	2.00	7.34	16.63	0.12	0.05
IH-2	2.75	7.88	7.02	0.39	0.07
IH-5	25.00	8.33	2.97	8.42	0.60
IH-6	37.50	8.49	2.18	17.20	0.89
IH-8	35.00	8.57	1.87	18.68	0.83
IH-10	6.00	8.59	1.80	3.33	0.14
IH-11	25.00	8.21	3.75	6.66	0.60
IH-12	3.00	7.90	6.77	0.44	0.07
IH-13	10.75	8.26	3.40	3.16	0.26
IH-15	0.75	7.45	14.30	0.05	0.02

[1] The pH dependent relationship for the WQC-FA is presented as : $[0.275/(1 + 10^{7.204-pH})] + [39.0//(1 + 10^{pH-7.204})]$

[2] Hazard Quotient based on the high pH LC_{20} for *Hyalella* from this study: 42 mg/L

Appendix A.
Analytical Chemistry – Results and Calculated Values

Appendix A-1.
Chemical concentrations.

Appendix A-1-1. Measured sediment concentrations of chemicals for the Indian Head TIE study.

Class	Analyte	IH-01-CMP	IH-02-CMP	IH-03-CMP	IH-04-CMP	IH-05-CMP	IH-06-CMP	IH-07-CMP	IH-08-CMP	IH-09-CMP	IH-10-CMP	IH-11-CMP	IH-12-CMP	IH-13-CMP	IH-14-CMP	IH-15-CMP
MET	Aluminum, total	766	1020	1090	9120	9000	9170	9060	9480	7530	6270	6190	4280	2870	4280	1480
MET	Arsenic	0.83 B	0.37 B	0.57 B	4.5	6.1	6.0	3.6 B	4.6	5.0	2.1 B	2.7	3.5	2.2	2.0	53.6
MET	Cadmium	0.030 U	0.060 B	0.020 U	0.15 B	0.31 B	0.45 B	0.21 B	0.32 B	1.8 B	0.87 B	0.050 U	0.73 B	0.87	0.11 B	32.1
MET	Chromium	4.2	4.8	5.6	21.5	18.9	21.4	20.7	21.8	15.6	14.1	14.7	10.2	9.5	8.3	5.3
MET	Copper	4.8 EN	3.6 EN	1.6 EN	20.3 EN	20.9 EN	20.5 EN	19.2 EN	19.3 EN	28.6 EN	32.1 EN	14.0 EN	10.6 EN	13.9 EN	6.6 EN	100 EN
MET	Iron	4330 E	3690 E	4690 E	25500 E	21100 E	26400 E	24600 E	25000 E	32300 E	36100 E	17800 E	20000 E	13500 E	11100 E	6860 E
MET	Lead	20.1 E	12.7 E	3.8 E	32.2 E	30.9 E	32.7 E	31.2 E	32.4 E	28.6 E	26.8 E	21.8 E	20.8 E	28.5 E	17.6 E	1010 E
MET	Manganese	56.9	73.0	23.7	1040	587	1090	852	1070	435	542	571	262	153	209	75.8
MET	Nickel	5.6	3.6 B	4.4 B	22.9	22.9	23.1	21.8	23.9	20.5	16.9	15.3	12.7	6.5	10.2	17.7
MET	Silver	5.1	203	0.20 U	2.4 B	1.3 B	2.4 B	1.3 B	1.5 B	12.2	25.3	1.1 B	24.9	4.8	4.1	0.29 U
MET	Zinc	67.9 E	24.9 E	11.1 E	145 E	138 E	142 E	144 E	150 E	265 E	152 E	70.0 E	89.8 E	120 E	41.8 E	21600 E
MET	SEM-AVS	0.9	0.5	-2.3E-1	2.4	-1.4E+1	1.7	-1.7E+2	-1.0E+0	784	-9.3E+0	-2.9E+0	-9.2E+0	1.8	0.3	270
PAH	1-Methylnaphthalene	2.8 U	6.1	2.6 U	6.0 J	5.7 J	25.0 U	4.2 J	5.0 J	7.4 J	13.0 U	4.8 U	4.3 U	7.7	2.4 J	1.5 J
PAH	1-Methylphenanthrene	2.8 J	14.0	2.6 U	7.7 J	81.0	13.0 J	8.1	9.7	13.0	15.0	4.0 J	5.7	54.0	5.9	13.0
PAH	2,3,5 Trimethylnaphthalene	2.8 U	2.6 J	2.6 U	8.3 U	9.8	25.0 U	3.9 J	4.0 J	9.5 U	13.0 U	4.8 U	2.8 J	4.9	2.1 J	2.0 J
PAH	2,6 Dimethylnaphthalene	2.8 U	4.2	2.6 U	6.2 J	9.3	25.0 U	5.6 J	6.3 J	10.0	13.0 U	3.0 J	3.0 J	6.9	2.2 J	2.0 J
PAH	2-Methylnaphthalene	2.8 U	9.6	2.6 U	11.0	9.6	25.0 U	7.5	8.8	6.1 J	13.0 U	3.2 J	2.5 J	9.0	2.4 J	1.8 J
PAH	Acenaphthene	1.9 J	35.0	2.6 U	8.3 U	13.0	25.0 U	7.1 U	3.9 J	39.0	40.0	4.8 U	16.0	82.0	13.0	8.6
PAH	Acenaphthylene	2.8 U	2.9	2.6 U	8.3 U	30.0	25.0 U	7.1 U	5.4 J	22.0	7.5 J	4.8 U	4.3 U	15.0	2.1 J	2.2 J
PAH	Anthracene	8.7	55.0	2.6 U	9.0	99.0	16.0 J	10.0	13.0	50.0	50.0	7.9	16.0	270 E	15.0	25.0
PAH	Benzo(a)anthracene	30.0	260 E	1.5 J	54.0	840 E	88.0	54.0	78.0	220	240	40.0	78.0	1400 E	97.0	65.0
PAH	Benzo[a]pyrene	37.0	200 E	2.6 U	62.0	540 E	99.0	61.0	92.0	220	280	45.0	74.0	1600 E	87.0	60.0
PAH	Benzo[b]fluoranthene	34.0	230 E	1.7 J	73.0	670 E	110	69.0	100	290	440	43.0	97.0	1700 E	98.0	77.0
PAH	Benzo[e]pyrene	26.0	170 E	2.6 U	53.0	410 E	79.0	48.0	70.0	160	290	32.0	61.0	1000 E	70.0	54.0
PAH	Benzo[ghi]perylene	34.0	140 E	2.6 U	58.0	280	85.0	54.0	79.0	120	200	42.0	56.0	910 E	63.0	42.0
PAH	Benzo[k]fluoranthene	30.0	190 E	1.6 J	63.0	590 E	91.0	52.0	76.0	220	290	37.0	73.0	1200 E	70.0	61.0
PAH	Biphenyl	2.8 U	2.6 J	2.6 U	8.3 U	3.0 J	25.0 U	7.1 U	7.4 U	9.5 U	13.0 U	4.8 U	4.3 U	3.3 J	3.9 U	3.0 U
PAH	Chrysene	34.0	240 E	2.0 J	71.0	720 E	110	66.0	98.0	250	350	44.0	88.0	1400 E	98.0	99.0
PAH	Dibenzothiophene	1.7 J	13.0	2.6 U	8.3 U	16.0	25.0 U	7.1 U	3.9 J	6.5 J	14.0	4.8 U	5.2	40.0	3.8 J	13.0
PAH	Dibenz[a,h]anthracene	17.0	98.0	2.6 U	27.0	220	51.0	28.0	41.0	66.0	96.0	14.0	25.0	470 E	34.0	22.0
PAH	Fluoranthene	87.0	340 E	1.6 J	100	2100 E	170	99.0	150	430	440	70.0	160	1900 E	180	360 E
PAH	Fluorene	2.8 U	29.0	2.6 U	7.6 J	30.0	13.0 J	8.5	11.0	34.0	48.0	4.8 J	18.0	66.0	10.0	17.0
PAH	Indeno[1,2,3-cd]pyrene	31.0	160 E	2.6 U	57.0	360 E	84.0	52.0	79.0	150	210	38.0	58.0	1100 E	66.0	43.0
PAH	Naphthalene	2.8 U	12.0	2.6 U	9.7	7.8	25.0 U	5.3 J	6.4 J	7.3 J	13.0 U	2.7 J	2.7 J	15.0	3.5 J	2.2 J
PAH	Perylene	12.0	83.0	2.6 U	380	550 E	490	440 E	440 E	66.0	300	110	240 E	380 E	460 E	32.0
PAH	Phenanthrene	33.0	210 E	2.6 U	33.0	520 E	56.0	34.0	45.0	78.0	130	18.0	57.0	780 E	55.0	200 E
PAH	Pyrene	78.0	280 E	1.3 J	97.0	1500 E	170	94.0	140	360	420	64.0	140	1400 E	160	250 E
PAH	Total LMW (L) PAHs	54.8	354	18.2	86.9	709	185	79.5	93.5	236	302	46.2	117	1237	101	257
PAH	Total HMW (H) PAHs	283	1418	11.6	411	5920	688	402	599	1546	1826	277	565	8170	656	856
PAH	Total LMW+HMW PAHs	338	1772	29.8	498	6629	873	482	693	1782	2128	323	682	9407	757	1113

Units: metals = mg/kg; PCBs, Pesticides (PST), PAHs, Explosives (EXP) = ng/g;
SEM-AVS= µM/g.
LMW PAH = sum of 7 2-ring & 3-ring PAHs included in NOAA ER-L/ER-M benchmarks (Long et al. 1995);
(methylnaphthalene, acenaphthene, acenaphthylene, anthracene, fluorene, naphthalene, phenanthrene)
HMW PAH = sum of 6 4-ring and 5-ring PAHs included in NOAA ER-L/ER-M benchmarks (Long et al. 1995);
(benzo(a)anthracene, benzo(a)pyrene, chrysene, dibenz(a,h)anthracene, fluoranthene, pyrene)
Total PAHs - sum of LMW & HMW PAHs; Total PCBs - Sum of individual PCB congeners x 2
Data Qualifiers: "U"=Undetected, "J"=Estimated, "B"=also present in method blank, "E"=exceeds calibration range,
C=manual spectrophotometric method, "D"=value from secondary dilution, "M"=duplicate precision not met,
N=presumptive evidence of compound, "P"=>25% difference between GC columns, "B"=<reporting limit.

Appendix A-1-1. continued.

Class	Analyte	IH-01-CMP	IH-02-CMP	IH-03-CMP	IH-04-CMP	IH-05-CMP	IH-06-CMP	IH-07-CMP	IH-08-CMP	IH-09-CMP	IH-10-CMP	IH-11-CMP	IH-12-CMP	IH-13-CMP	IH-14-CMP	IH-15-CMP
PCB	PCB 101	0.5 P	6.6	0.3 P	0.4 P	1.1 P	0.8 P	1.1 P	0.3 P	2.3 P	6.2	0.5 P	3.4 P	43.0 E	1.6 P	0.5 P
PCB	PCB 105	0.2 U	2.5 BP	0.2 U	0.4 U	0.7 BP	0.4 U	0.3 U	0.3 U	1.0 BP	2.3 BP	0.2 U	1.1 BP	16.0 BEP	0.7 BP	0.2 U
PCB	PCB 118	0.1 U	6.1 P	0.1 U	0.5 P	0.8 P	0.8 P	1.1 P	0.3 P	2.7	5.2 P	0.4 P	3.0	34.0 EP	1.5	0.1 P
PCB	PCB 126	0.3 P	0.7	0.0 U	0.1 P	0.3 P	0.2 P	0.5 P	0.1 U	0.4 P	0.8	0.1 U	0.5 P	3.8 P	0.7	0.3 P
PCB	PCB 128	0.2 P	1.8 P	0.1 P	0.5 P	0.5 P	0.7 P	0.8 P	0.3 P	1.2 P	1.5 P	0.3 P	1.0 P	7.0 P	0.7 P	0.3
PCB	PCB 138	0.3 P	6.4	0.0 U	0.7 P	1.9 P	1.2 P	1.3 P	0.4 P	3.1	5.7	0.5 P	3.3	28.0 E	1.8	0.2 P
PCB	PCB 153	0.4 P	4.8 P	0.0 U	1.0 P	1.9 P	1.5 P	1.4 P	0.6 P	2.6 P	4.9 P	0.6 P	40.0 P	23.0 P	1.5 P	0.2 P
PCB	PCB 156	0.1 U	1.1	0.1	0.4 P	0.3 P	0.5 P	0.5 P	0.3 P	0.6 P	1.0 P	0.2 P	0.6	5.5 P	0.3 P	0.2 P
PCB	PCB 169	0.1 U	0.1 U	0.1 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
PCB	PCB 170	0.1 U	0.9	0.1 J	0.5 P	0.6 P	0.6 P	0.9 P	0.3 P	0.5	0.9	0.2 P	0.6	2.6	0.3	0.1
PCB	PCB 18	0.1 U	1.4 BP	0.1 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.5 BP	0.1 U	0.1 U	9.3 BP	0.1 U	0.1 BP
PCB	PCB 180	0.3 P	1.1 P	0.1 U	0.7	1.1 P	0.9 P	1.3	0.4 P	0.7 P	1.3	0.3 P	0.8 P	0.1 U	0.5 P	0.2 P
PCB	PCB 183	0.1 U	0.5 P	0.1 U	0.2 P	0.4 P	0.2 P	0.4 P	0.2 P	0.6 P	0.7 P	0.1 U	0.5	1.4 P	0.3 P	0.2 P
PCB	PCB 184	0.1 U	1.0 P	0.1 U	0.5	0.3 P	0.8	0.6 P	0.4	0.8 P	1.1 P	0.6 P	2.2 P	2.4 P	0.7	0.2
PCB	PCB 187	0.1 U	0.6 BP	0.1 U	0.1 U	0.7 BP	0.1 U	0.1 U	0.1 U	0.1 U	8.4 BP	0.1 U	0.1 U	2.0 BP	0.1 U	0.1 U
PCB	PCB 195	0.1 U	0.1 U	0.1 U	0.4 P	0.1 U	0.2 U	0.2 U	0.2 U	0.2 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
PCB	PCB 206	0.1 U	0.2	0.1 U	0.9 P	0.2 U	0.3 U	0.2 U	0.3 U	0.3 U	0.2 U	0.2 U	0.2 P	0.4 P	0.1 U	0.3 P
PCB	PCB 209	0.2 U	0.2 U	0.2 U	0.3 U	0.3 U	0.4 U	0.3 U	0.3 U	0.3 U	0.3 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2
PCB	PCB 28	0.0 U	1.8 P	0.1 P	0.1 U	0.1 U	0.1 U	0.4	0.1 U	0.1 U	2.2 P	0.3 P	0.0 U	26.0 E	0.7 P	0.0 U
PCB	PCB 44	0.3 P	2.2 P	0.1 P	0.4 P	0.6 P	0.8 P	0.7 P	0.4 P	1.2 P	2.4 P	0.7	1.4 P	18.0 EP	0.9 P	0.1 P
PCB	PCB 49	0.2 U	2.2	0.2 U	0.4 U	0.3	0.4 U	0.4 P	0.3 U	0.7	2.5	0.4 P	0.3 P	11.0 EP	0.4 P	0.2 U
PCB	PCB 52	0.1 U	4.0 P	0.1 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	3.9 P	0.1 U	2.6 P	35.0 EP	1.2 P	0.1 U
PCB	PCB 66	0.3	2.9 P	0.1	0.6 P	0.7 P	0.9	0.9 P	0.4 P	1.6 P	3.0 P	0.8 P	1.0 P	21.0 EP	1.0 P	0.3
PCB	PCB 77	0.1 U	10.0	0.1 U	0.4 P	1.4 P	0.4 P	1.9	0.2 U	4.2	9.8	0.8 P	5.3 P	103 E	3.1	0.2 P
PCB	PCB 8	0.2 P	0.6 P	0.2	0.2 U	0.4 P	0.6	0.2 U	0.2 U	0.2 U	0.6 P	0.3 P	0.1 U	7.7 P	0.3 P	0.1 U
PCB	PCB 87	0.0 U	3.2 P	0.0 U	0.3 P	0.6 P	0.4 P	0.5 P	0.2 P	1.4 P	3.0 P	0.4 P	2.4	28.0 E	0.9 P	0.0 U
PCB	Total (Sumx2) PCBs	8.6	126	5.3	21.1	31.8	27.6	33.3	13.7	54.5	137	16.9	141	857	39.3	9.5
PST	2,4'-DDD	0.7 U	0.7 U	0.7 U	1.5 U	1.2 U	1.6 U	1.3 U	1.4 U	1.5 U	1.1 U	0.9 P	1.1 P	50.0 P	1.3 P	0.7 U
PST	2,4'-DDE	0.6 U	0.6 U	0.6 U	1.2 U	0.9 U	1.3 U	1.0 U	1.1 U	1.2 U	0.9 U	0.7 U	0.9 P	7.9 P	0.6 U	0.6 U
PST	2,4'-DDT	1.5	6.6 P	0.3 U	1.0 P	0.5 U	0.7 U	0.6 U	0.6 U	0.7 U	0.5 U	0.4 U	0.8 P	0.3 U	0.3 U	0.3 U
PST	4,4'-DDD	0.4 U	1.8 P	0.4 U	0.9 U	0.7 U	1.0 U	0.8 U	1.0 P	0.9 U	0.7 U	0.6 P	0.4 U	0.4 U	0.4 U	0.4 U
PST	4,4'-DDE	0.4 U	4.8 P	0.4 U	0.8 U	0.7 P	0.9 U	0.7 U	0.8	0.8 U	0.6 U	0.5 U	0.8 P	17.0 P	1.5	0.4 U
PST	4,4'-DDT	0.7 U	3.3 P	0.7 U	1.4 U	1.1 U	1.5 U	1.2 U	1.3 U	1.4 U	1.1 U	0.8 U	0.7 U	7.1 P	0.7 U	0.7 U
PST	Aldrin	0.5 U	0.5 U	0.5 U	1.1 U	0.9 U	1.2 U	1.0 U	1.0 U	1.1 U	0.8 U	0.6 U	0.5 U	10.0 P	0.5 U	0.5 U
PST	alpha-BHC	0.4 U	0.4 U	0.4 U	0.8 U	0.6 U	0.9 U	0.7 U	0.7 U	0.8 U	0.6 U	0.5 U	0.4 U	0.9 P	0.4 U	0.4 U
PST	alpha-Chlordane	0.7 U	44.0 EP	0.7 U	2.4 P	1.2 U	1.6 U	1.3 U	1.4 U	1.5 U	1.1 U	0.9 U	0.7 U	1.0 P	0.7 U	0.7 U
PST	beta-BHC	2.5	9171 P	0.5 U	295 EP	0.8 U	28.0 P	4.1 P	0.9 U	1.0 U	1.4 P	0.8 P	0.5 U	2.0 P	0.5 U	0.7 P
PST	delta-BHC	0.5 U	0.5 U	0.5 U	1.0 U	0.8 U	1.1 U	0.9 U	0.9 U	1.0 U	0.8 U	0.6 U	0.5 U	0.5 U	0.5 U	0.5 U
PST	Dieldrin	0.4 U	0.7 P	0.4 U	0.9 U	0.7 U	1.0 U	0.8 U	0.8 U	0.9 U	0.7 U	0.5 U	0.4 U	10.0 P	0.4 U	0.4 U
PST	Endosulfan I	0.7 U	0.7 U	0.7 U	1.5 U	1.2 U	1.6 U	1.3 U	1.4 U	1.5 U	1.2 U	0.9 U	0.7 U	1.1 P	0.7 U	0.7 U
PST	Endosulfan II	0.4 U	1.0 P	0.4 U	0.8 U	0.6 U	0.8 U	0.7 U	0.7	0.8 U	0.6 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
PST	Endosulfan sulfate	0.8 U	0.8 U	0.8 U	1.7 U	1.4 U	1.9 U	1.6 U	1.6 U	1.8 U	1.4 U	1.0 U	0.9 U	2.0 P	0.8 U	0.8 U
PST	Endrin	1.5 U	1.1 J	1.5 U	3.1 U	2.5 U	3.4 U	2.8 U	2.9 U	3.1 U	2.4 U	1.8 U	1.5 U	1.5 U	1.5 U	1.5 U
PST	Endrin aldehyde	0.9 U	1.4 P	0.9 U	2.0 U	1.6 U	2.1 U	1.7 U	1.8 U	2.0 U	1.6 P	1.1 U	1.0 U	4.1 P	0.9 U	0.9 U
PST	Endrin ketone	0.7 U	0.7 U	0.7 U	1.5 U	1.2 U	1.6 U	1.3 U	1.4 U	1.5 U	1.1 U	0.9 U	0.7 U	1.8 P	0.7 U	0.7 U
PST	gamma-BHC	0.5 U	0.5 U	0.5 U	0.9 U	0.8 U	1.0 U	0.8 U	0.9 U	0.9 U	0.7 U	0.6 U	0.5 U	0.4 U	0.5 U	0.5 U
PST	gamma-Chlordane	0.4 U	5.7 P	0.4 U	0.7 U	0.6 U	0.8 U	0.7 U	0.7 U	0.7 U	0.6 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
PST	Heptachlor	0.6 U	0.6 U	0.6 U	1.2 U	1.0 U	1.4 U	1.1 U	1.2 U	1.3 U	1.0 U	0.7 U	0.6 U	0.6 U	0.6 U	0.6 U
PST	Heptachlor epoxide	0.9	18.0 P	0.8 U	1.7 U	1.4 U	1.8 U	1.5 U	1.6 U	1.7 U	1.3 U	1.0 U	0.8 U	22.0	0.8 U	1.2 P
PST	Hexachlorobenzene	0.8 U	0.8 U	0.8 U	1.7 U	1.4 U	1.9 U	1.6 U	1.6 U	1.8 U	1.4 U	1.0 U	0.9 U	0.8 U	0.8 U	0.8 U
PST	Methoxychlor	14.0 P	2.6 U	2.6 U	5.4 U	4.3 U	5.9 U	4.8 U	5.0 U	5.4 U	4.2 U	3.2 U	2.6 U	2.6 U	2.6 U	2.6 U
PST	Mirex	3.3 U	3.3 U	3.3 U	6.9 U	5.5 U	7.5 U	6.2 U	6.4 U	6.9 U	5.4 U	4.0 U	3.4 U	3.4 P	3.3 U	3.3 U
PST	Toxaphene	14.0 U	14.0 U	14.0 U	29.0 U	23.0 U	32.0 U	26.0 U	27.0 U	29.0 U	23.0 U	17.0 U	14.0 U	14.0 U	14.0 U	14.0 U

Appendix A-1-1. continued.

Class	Analyte	IH-01-CMP	IH-02-CMP	IH-03-CMP	IH-04-CMP	IH-05-CMP	IH-06-CMP	IH-07-CMP	IH-08-CMP	IH-09-CMP	IH-10-CMP	IH-11-CMP	IH-12-CMP	IH-13-CMP	IH-14-CMP	IH-15-CMP
EXP	1,3,5-Trinitrobenzene	84.0 U	82.0 U	82.0 U	173 U	138 U	189 U	154 U	160 U	173 U	134 U	101 U	85.0 U	79.0 U	84.0 U	84.0 U
EXP	1,3-Dinitrobenzene	73.0 U	72.0 U	72.0 U	152 U	122 U	166 U	135 U	140 U	152 U	118 U	89.0 U	75.0 U	69.0 U	74.0 U	74.0 U
EXP	2,4,6-Trinitrotoluene	181 U	179 U	78.0 U	375 U	300 U	409 U	333 U	346 U	375 U	290 U	220 U	184 U	170 U	182 U	182 U
EXP	2,4-Dinitrotoluene	87.0 U	85.0 U	85.0 U	179 U	143 U	195 U	159 U	165 U	179 U	139 U	105 U	88.0 U	81.0 U	87.0 U	87.0 U
EXP	2,6-Dinitrotoluene	201 U	198 U	198 U	417 U	333 U	455 U	370 U	385 U	417 U	323 U	244 U	204 U	189 U	202 U	202 U
EXP	2-Amino-4,6-dinitrotoluene	141 U	139 U	138 U	292 U	233 U	318 U	259 U	269 U	292 U	226 U	171 U	143 U	133 U	141 U	141 U
EXP	2-Nitrotoluene	151 U	149 U	148 U	313 U	250 U	341 U	278 U	288 U	313 U	242 U	183 U	153 U	142 U	152 U	152 U
EXP	3-Nitrotoluene	231 U	228 U	227 U	479 U	383 U	523 U	426 U	442 U	479 U	371 U	280 U	235 U	218 U	232 U	232 U
EXP	4-Amino-2,6-dinitrotoluene	221 U	218 U	217 U	458 U	367 U	500 U	407 U	423 U	458 U	355 U	268 U	224 U	208 U	222 U	222 U
EXP	4-Nitrotoluene	121 U	119 U	119 U	250 U	200 U	273 U	222 U	231 U	250 U	194 U	146 U	122 U	114 U	121 U	121 U
EXP	HMX	191 U	188 U	188 U	396 U	317 U	432 U	352 U	365 U	396 U	306 U	232 U	1916	180 U	192 U	192 U
EXP	Nitrobenzene	111 U	1056	109 U	229 U	183 U	250 U	204 U	212 U	229 U	177 U	134 U	112 U	104 U	111 U	111 U
EXP	RDX	181 U	179 U	178 U	375 U	300 U	409 U	333 U	346 U	375 U	290 U	220 U	184 U	170 U	182 U	182 U
EXP	Tetryl	241 U	238 U	237 U	500 U	400 U	545 U	444 U	462 U	500 U	387 U	293 U	245 U	227 U	242 U	242 U
TOC	TOC(%)	0.5	0.5	0.7	17.6	12.6	18.1	13.8	14.6	26.3	11.8	5.1	5.9	1.4	3.2	1.7

Appendix A-1-2. Measured pore water concentrations of metals for the Indian Head TIE study.

Class	Analyte	IH-01-PW	IH-02-PW	IH-03-PW	IH-04-PW	IH-05-PW	IH-06-PW	IH-07-PW	IH-08-PW	IH-09-PW	IH-10-PW	IH-11-PW	IH-12-PW	IH-13-PW	IH-14-PW	IH-15-PW	IH-SPIKE
MET	Aluminum, total	4140	347			36 B	48 B		46 B		102 B	27 U	950	36 B		870	27 U
MET	Arsenic	8.0 B	1.7 U			1.7 U	1.7 U		1.7 U		1.7 U	5.7 B	1.7 U	1.7 U		32	1.7 U
MET	Cadmium	1.7 B	0.3 B			0.2 U	0.2 U		0.2 U		0.2 U	0.2 U	0.6 B	0.2 U		11	0.3 B
MET	Chromium	17	5.8 B			6.3 B	8.1 B		9.9 B		5.1 B	11	10	5.9 B		6.4 B	3.7 B
MET	Copper	59	9.8 B			1.3 B	1.8 B		0.9 B		1.5 B	4.8 B	5.7 B	2.1 B		43	2.1 B
MET	Iron	18800 E	2900 E			6840 E	2190 E		4740 E		11700 E	18000 E	24000 E	24900 E		4890 E	35 BE
MET	Lead	142	8.4			1.3 B	2.1 B		4.6		1.2 B	6.5	6.9	9.8		161	3.5
MET	Manganese	2370	2830			7490	18700		24000		2980	23200	3100	6170		799	3.5 B
MET	Nickel	19	4.8 B			2.4 U	2.4 U		4.2 B		2.4 U	3.9 B	12	4.3 B		2.7 B	2.4 U
MET	Silver	33	42			2.2 B	3.5 B		4.6 B		2.5 B	4.8 B	6.1 B	2.2 U		2.2 U	44
MET	Zinc	607	30			23	20		8.6 U		8.6 U	8.6 U	58	8.6 U		25000	8.6 U

Units = µg/l.
Data Qualifiers: "U"=Undetected, "J"=Estimated, "B"=also present in method blank, "E"=exceeds calibration range,
C=manual spectrophotometric method, "D"=value from secondary dilution, "M"=duplicate precision not met,
N=presumptive evidence of compound, "P"=>25% difference between GC columns, "B"=<reporting limit.

Appendix A-1-3. Predicted pore water concentrations of organics for the Indian Head TIE investigation[1].

Class	Analyte	Koc	IH-01	IH-02	IH-03	IH-04	IH-05	IH-06	IH-07	IH-08	IH-09	IH-10	IH-11	IH-12	IH-13	IH-14	IH-15
PAH	1-Methylnaphthalene	8.0E+03	6.5E-2	0.1	4.9E-2	4.3E-3	5.7E-3	1.7E-2	3.8E-3	4.3E-3	3.5E-3	1.4E-2	1.2E-2	9.1E-3	7.1E-2	9.3E-3	1.1E-2
PAH	1-Methylphenanthrene	9.9E+04	5.3E-3	2.8E-2	4.0E-3	4.4E-4	6.5E-3	7.3E-4	6.0E-4	6.7E-4	5.0E-4	1.3E-3	8.0E-4	9.8E-4	4.0E-2	1.9E-3	7.7E-3
PAH	2,3,5 Trimethylnaphthalene	NA															
PAH	2,6 Dimethylnaphthalene	3.4E+04	1.5E-2	2.4E-2	1.2E-2	1.0E-3	2.2E-3	4.1E-3	1.2E-3	1.3E-3	1.1E-3	3.2E-3	1.7E-3	1.5E-3	1.5E-2	2.0E-3	3.4E-3
PAH	2-Methylnaphthalene	8.0E+03	6.5E-2	0.2	4.9E-2	7.8E-3	9.5E-3	1.7E-2	6.8E-3	7.5E-3	2.9E-3	1.4E-2	7.9E-3	5.3E-3	8.3E-2	9.3E-3	1.3E-2
PAH	Acenaphthene	7.1E+03	5.0E-2	1.0	5.5E-2	6.6E-3	1.4E-2	1.9E-2	7.2E-3	3.7E-3	2.1E-2	4.7E-2	1.3E-2	3.8E-2	0.8	5.7E-2	7.0E-2
PAH	Acenaphthylene	9.6E+03	5.5E-2	5.9E-2	4.1E-2	4.9E-3	2.5E-2	1.4E-2	5.4E-3	3.9E-3	8.7E-3	6.6E-3	9.9E-3	7.6E-3	0.1	6.8E-3	1.3E-2
PAH	Anthracene	3.0E+04	5.5E-2	0.4	1.3E-2	1.7E-3	2.6E-2	3.0E-3	2.4E-3	3.0E-3	6.4E-3	1.4E-2	5.3E-3	9.1E-3	0.7	1.6E-2	4.9E-2
PAH	Benzo(a)anthracene	4.0E+05	1.4E-2	0.1	5.6E-4	7.6E-4	1.7E-2	1.2E-3	9.8E-4	1.3E-3	2.1E-3	5.1E-3	2.0E-3	3.3E-3	0.3	7.5E-3	9.5E-3
PAH	Benzo[a]pyrene	1.0E+06	6.8E-3	3.8E-2	3.9E-4	3.5E-4	4.2E-3	5.4E-4	4.4E-4	6.2E-4	8.2E-4	2.3E-3	8.8E-4	1.2E-3	0.1	2.7E-3	3.5E-3
PAH	Benzo[b]fluoranthene	1.2E+06	5.1E-3	3.6E-2	2.1E-4	3.3E-4	4.3E-3	4.9E-4	4.0E-4	5.5E-4	8.9E-4	3.0E-3	6.8E-4	1.3E-3	0.1	2.4E-3	3.6E-3
PAH	Benzo[e]pyrene	1.0E+06	4.8E-3	3.3E-2	3.9E-4	3.0E-4	3.2E-3	4.3E-4	3.4E-4	4.7E-4	6.0E-4	2.4E-3	6.2E-4	1.0E-3	7.2E-2	2.1E-3	3.1E-3
PAH	Benzo[ghi]perylene	3.9E+06	1.6E-3	7.1E-3	1.0E-4	8.5E-5	5.8E-4	1.2E-4	1.0E-4	1.4E-4	1.2E-4	4.4E-4	2.2E-4	2.5E-4	1.7E-2	5.1E-4	6.4E-4
PAH	Benzo[k]fluoranthene	1.2E+06	4.5E-3	3.0E-2	1.9E-4	2.9E-4	3.8E-3	4.0E-4	3.0E-4	4.2E-4	6.7E-4	2.0E-3	5.9E-4	9.9E-4	7.1E-2	1.7E-3	2.9E-3
PAH	Biphenyl	7.8E+03	6.7E-2	6.5E-2	5.0E-2	6.0E-3	3.0E-3	1.8E-2	6.6E-3	6.5E-3	4.6E-3	1.4E-2	1.2E-2	9.3E-3	3.1E-2	1.5E-2	2.2E-2
PAH	Chrysene	4.0E+05	1.6E-2	0.1	7.5E-4	1.0E-3	1.4E-2	1.5E-3	1.2E-3	1.7E-3	2.4E-3	7.4E-3	2.2E-3	3.7E-3	0.3	7.6E-3	1.4E-2
PAH	Dibenzothiophene	NA															
PAH	Dibenz[a,h]anthracene	3.8E+06	8.4E-4	5.1E-3	1.0E-4	4.1E-5	4.6E-4	7.5E-5	5.4E-5	7.4E-5	6.7E-5	2.2E-4	7.3E-5	1.1E-4	9.2E-3	2.8E-4	3.4E-4
PAH	Fluoranthene	1.1E+05	0.2	0.6	2.2E-3	5.3E-3	0.2	8.7E-3	6.6E-3	9.5E-3	1.5E-2	3.5E-2	1.3E-2	2.5E-2	1.3	5.2E-2	0.2
PAH	Fluorene	1.4E+04	3.8E-2	0.4	2.8E-2	3.1E-3	1.7E-2	5.2E-3	4.5E-3	5.5E-3	9.4E-3	3.0E-2	6.9E-3	2.2E-2	0.4	2.3E-2	7.2E-2
PAH	Indeno[1,2,3-cd]pyrene	3.4E+06	1.7E-3	9.0E-3	1.1E-4	9.4E-5	8.3E-4	1.3E-4	1.1E-4	1.6E-4	1.7E-4	5.2E-4	2.2E-4	2.8E-4	2.3E-2	5.9E-4	7.3E-4
PAH	Naphthalene	2.0E+03	0.3	1.2	0.2	2.7E-2	3.1E-2	6.9E-2	1.9E-2	2.2E-2	1.4E-2	5.5E-2	2.7E-2	2.3E-2	0.5	5.4E-2	6.4E-2
PAH	Perylene	8.9E+05	2.5E-3	1.8E-2	4.4E-4	2.4E-3	4.9E-3	3.1E-3	3.6E-3	3.4E-3	2.8E-4	2.9E-3	2.5E-3	4.6E-3	3.2E-2	1.6E-2	2.1E-3
PAH	Phenanthrene	3.0E+04	0.2	1.4	1.3E-2	6.3E-3	0.1	1.0E-2	8.3E-3	1.0E-2	1.0E-2	3.7E-2	1.2E-2	3.2E-2	1.9	5.7E-2	0.4
PAH	Pyrene	1.1E+05	0.1	0.5	1.9E-3	5.2E-3	0.1	8.9E-3	6.5E-3	9.1E-3	1.3E-2	3.4E-2	1.2E-2	2.2E-2	1.0	4.7E-2	0.1
PAH	Total LMW (L) PAHs	NA	0.7	4.6	0.4	5.8E-2	0.3	0.1	5.4E-2	5.6E-2	7.2E-2	0.2	8.2E-2	0.1	4.5	0.2	0.7
PAH	Total HMW (H) PAHs	NA	0.3	1.4	5.9E-3	1.3E-2	0.3	2.1E-2	1.6E-2	2.2E-2	3.3E-2	8.3E-2	3.0E-2	5.6E-2	2.9	0.1	0.4
PAH	Total LMW+HMW PAHs	7.6E+04	1.1	4.6	5.9E-2	3.7E-2	0.7	6.4E-2	4.6E-2	6.3E-2	9.0E-2	0.2	8.5E-2	0.2	9.2	0.3	0.9
PCB	Total (Sumx2) PCBs	2.7E+06	6.0E-4	9.1E-3	3.0E-4	4.5E-5	9.4E-5	5.7E-5	9.0E-5	3.5E-5	7.7E-5	4.3E-4	1.2E-4	8.9E-4	2.3E-2	4.5E-4	2.1E-4

1- Predicted concentration = sediment conc. (Appendix A-1-1)/(Koc *%TOC (Appendix A-1-1)*0.01).
units = µg/L
LMW PAH = sum of 7 2-ring & 3-ring PAHs included in NOAA ER-L/ER-M benchmarks (Long et al. 1995);
(methylnaphthalene, acenaphthene, acenaphthylene, anthracene, fluorene, naphthalene, phenanthrene)
HMW PAH = sum of 6 4-ring and 5-ring PAHs included in NOAA ER-L/ER-M benchmarks (Long et al. 1995);
(benzo(a)anthracene, benzo(a)pyrene, chrysene, dibenz(a,h)anthracene, fluoranthene, pyrene)
Total PAHs - sum of LMW & HMW PAHs; Total PCBs - Sum of individual PCB congeners x 2

Appendix A-1-3. continued.

Class	Analyte	Koc	IH-01	IH-02	IH-03	IH-04	IH-05	IH-06	IH-07	IH-08	IH-09	IH-10	IH-11	IH-12	IH-13	IH-14	IH-15
PST	2,4'-DDD	9.9E+05	1.3E-4	1.4E-4	1.1E-4	8.6E-6	9.6E-6	8.9E-6	9.5E-6	9.7E-6	5.7E-6	9.4E-6	1.8E-5	1.9E-5	3.7E-3	4.1E-5	4.1E-5
PST	2,4'-DDE	4.4E+06	2.4E-5	2.4E-5	1.9E-5	1.5E-6	1.7E-6	1.6E-6	1.6E-6	1.7E-6	1.0E-6	1.7E-6	3.0E-6	3.6E-6	1.3E-4	3.9E-6	7.4E-6
PST	2,4'-DDT	4.4E+06	6.3E-5	2.9E-4	1.1E-5	1.2E-6	9.5E-7	9.0E-7	9.7E-7	9.6E-7	5.8E-7	9.8E-7	1.7E-6	3.2E-6	5.3E-6	2.2E-6	4.2E-6
PST	4,4'-DDD	9.9E+05	7.9E-5	3.5E-4	6.4E-5	5.0E-6	5.6E-6	5.3E-6	5.7E-6	6.6E-6	3.3E-6	5.8E-6	1.3E-5	7.3E-6	3.0E-5	1.3E-5	2.5E-5
PST	4,4'-DDE	4.4E+06	1.7E-5	2.1E-4	1.4E-5	1.1E-6	1.3E-6	1.1E-6	1.2E-6	1.2E-6	7.1E-7	1.2E-6	2.2E-6	3.1E-6	2.8E-4	1.1E-5	5.3E-6
PST	4,4'-DDT	4.4E+06	2.8E-5	1.5E-4	2.3E-5	1.8E-6	2.0E-6	1.9E-6	2.0E-6	2.0E-6	1.2E-6	2.1E-6	3.6E-6	2.6E-6	1.2E-4	4.6E-6	8.7E-6
PST	Aldrin	2.5E+06	4.0E-5	4.1E-5	3.2E-5	2.5E-6	2.8E-6	2.7E-6	2.8E-6	2.8E-6	1.7E-6	2.9E-6	5.1E-6	3.7E-6	3.0E-4	6.6E-6	1.2E-5
PST	alpha-BHC	5.4E+03	1.3E-2	1.4E-2	1.1E-2	8.2E-4	9.2E-4	8.7E-4	9.3E-4	9.2E-4	5.5E-4	9.5E-4	1.7E-3	1.2E-3	1.2E-2	2.2E-3	4.1E-3
PST	alpha-Chlordane	2.5E+06	5.3E-5	3.5E-3	4.3E-5	5.6E-6	3.9E-6	3.6E-6	3.8E-6	3.9E-6	2.3E-6	3.8E-6	6.9E-6	4.9E-6	3.0E-5	8.7E-6	1.7E-5
PST	beta-BHC	5.6E+03	8.4E-2	321	1.3E-2	0.3	1.2E-3	2.8E-2	5.3E-3	1.2E-3	6.8E-4	2.1E-3	2.9E-3	1.5E-3	2.6E-2	2.7E-3	7.1E-3
PST	delta-BHC	5.5E+03	1.7E-2	1.7E-2	1.3E-2	1.0E-3	1.2E-3	1.1E-3	1.2E-3	1.2E-3	6.9E-4	1.2E-3	2.1E-3	1.5E-3	6.4E-3	2.8E-3	5.2E-3
PST	Dieldrin	1.9E+05	4.2E-4	6.9E-4	3.4E-4	2.7E-5	3.0E-5	2.8E-5	3.0E-5	3.0E-5	1.8E-5	3.1E-5	5.4E-5	3.9E-5	3.9E-3	7.0E-5	1.3E-4
PST	Endosulfan I	NA															
PST	Endosulfan II	1.1E+04	6.3E-3	1.8E-2	5.1E-3	4.0E-4	4.4E-4	4.2E-4	4.5E-4	4.7E-4	2.7E-4	4.6E-4	8.1E-4	5.8E-4	2.5E-3	1.0E-3	2.0E-3
PST	Endosulfan sulfate	NA															
PST	Endrin	9.4E+04	3.0E-3	2.3E-3	2.4E-3	1.9E-4	2.1E-4	2.0E-4	2.2E-4	2.1E-4	1.3E-4	2.2E-4	3.8E-4	2.7E-4	1.2E-3	4.9E-4	9.3E-4
PST	Endrin aldehyde	NA															
PST	Endrin ketone	NA															
PST	gamma-BHC	4.6E+03	1.8E-2	1.9E-2	1.5E-2	1.1E-3	1.3E-3	1.2E-3	1.3E-3	1.3E-3	7.7E-4	1.3E-3	2.3E-3	1.7E-3	7.0E-3	3.0E-3	5.7E-3
PST	gamma-Chlordane	1.6E+06	4.0E-5	6.8E-4	3.2E-5	2.5E-6	2.8E-6	2.7E-6	2.9E-6	2.8E-6	1.7E-6	2.9E-6	5.1E-6	3.7E-6	1.6E-5	6.7E-6	1.3E-5
PST	Heptachlor	2.5E+06	4.6E-5	4.7E-5	3.7E-5	2.8E-6	3.2E-6	3.2E-6	3.2E-6	3.4E-6	2.0E-6	3.4E-6	5.9E-6	4.2E-6	1.8E-5	7.5E-6	1.4E-5
PST	Heptachlor epoxide	2.5E+06	7.1E-5	1.4E-3	5.0E-5	3.9E-6	4.5E-6	4.1E-6	4.4E-6	4.5E-6	2.6E-6	4.5E-6	7.9E-6	5.7E-6	6.6E-4	1.0E-5	2.9E-5
PST	Hexachlorobenzene	6.2E+05	2.5E-4	2.6E-4	2.1E-4	1.6E-5	1.8E-5	1.7E-5	1.9E-5	1.8E-5	1.1E-5	1.9E-5	3.2E-5	2.3E-5	9.9E-5	4.2E-5	8.0E-5
PST	Methoxychlor	NA															
PST	Mirex	5.9E+06	1.0E-4	1.1E-4	8.4E-5	6.6E-6	7.4E-6	7.0E-6	7.6E-6	7.4E-6	4.4E-6	7.7E-6	1.3E-5	9.7E-6	4.2E-5	1.7E-5	3.3E-5
PST	Toxaphene	NA															
EXP	1,3,5-Trinitrobenzene	NA															
EXP	1,3-Dinitrobenzene	NA															
EXP	2,4,6-Trinitrotoluene	2.5E+02	138	142	48	8.7	9.7	9.2	9.8	9.7	5.8	10	18	13	51	23	43
EXP	2,4-Dinitrotoluene	9.3E+01	175	178	138	11	12	12	12	12	7.3	13	22	16	64	29	55
EXP	2,6-Dinitrotoluene	NA															
EXP	2-Amino-4,6-dinitrotoluene	NA															
EXP	2-Nitrotoluene	NA															
EXP	3-Nitrotoluene	NA															
EXP	4-Amino-2,6-dinitrotoluene	NA															
EXP	4-Nitrotoluene	NA															
EXP	HMX	3.8E+00	9368	9615	7454	591	661	627	671	657	396	682	1208	8523	3479	1567	2952
EXP	Nitrobenzene	1.2E+02	174	1726	138	11	12	12	12	12	7.3	13	22	16	64	29	55
EXP	RDX	NA															
EXP	Tetryl	NA															

Appendix A-1-4. Measured concentrations of simultaneously extracted metals (SEM) and acid volatile sulfides (AVS) in sediments collected for the Indian Head TIE investigation.

Class	Analyte	IH-01-CMP	IH-02-CMP	IH-03-CMP	IH-04-CMP	IH-05-CMP	IH-06-CMP	IH-07-CMP	IH-08-CMP	IH-09-CMP	IH-10-CMP	IH-11-CMP	IH-12-CMP	IH-13-CMP	IH-14-CMP	IH-15-CMP
SEM	Cadmium	0.0E+0	0.0E+0	0.0E+0	1.0E-2	1.0E-2	1.0E-2	1.0E-2	1.0E-2	0.5	1.0E-2	0.0E+0	1.0E-2	1.0E-2	0.0E+0	0.2
SEM	Copper	7.0E-2	5.0E-2	1.0E-2	0.3	0.2	0.2	0.1	0.3	2.1	0.2	0.2	0.2	0.2	8.0E-2	1.2
SEM	Lead	7.0E-2	3.0E-2	1.0E-2	0.1	0.1	0.1	0.1	0.1	7.6	6.0E-2	9.0E-2	0.1	0.1	7.0E-2	2.9
SEM	Nickel	3.0E-2	3.0E-2	3.0E-2	0.2	0.2	0.3	0.3	0.2	0.6	0.1	0.1	0.1	0.2	6.0E-2	0.2
SEM	Silver	2.0E-2	0.2	0.0E+0	1.0E-2	0.0E+0	1.0E-2	0.0E+0	1.0E-2	0.0E+0	4.0E-2	1.0E-2	0.1	2.0E-2	1.0E-2	0.0E+0
SEM	Zinc	0.8	0.4	0.2	2.0	1.7	1.3	1.5	2.1	792	1.4	0.8	1.3	1.4	0.4	268
SEM	Sum SEM	1.0	0.6	0.2	2.7	2.2	2.0	2.1	2.7	803	1.8	1.1	1.8	1.9	0.7	272
AVS	Sulfide, acid volatile	7.0E-2 <	7.0E-2 <	0.4	0.2 <	17	0.2 <	168	3.7	19	11	4.1	11	9.0E-2 U	0.4	2.4
SEM	SEM-AVS	0.9	0.5	-2.3E-1	2.4	-1.4E+1	1.7	-1.7E+2	-1.0E+0	784	-9.3E+0	-2.9E+0	-9.2E+0	1.8	0.3	270

units = µM/g dry wt

Sum SEM = [Cu]+[Cd]+[Pb]+[Ni]+[Zn]+[Ag/2].

Appendix A-2.
Hazard Quotients.

Appendix A-2-1. Hazard Quotients for chemicals in sediment for the Indian Head TIE investigation.

Class	Analyte	Benchmark	Benchmark Source	IH-01	IH-02	IH-03	IH-04	IH-05	IH-06	IH-07	IH-08	IH-09	IH-10	IH-11	IH-12	IH-13	IH-14	IH-15
MET	Aluminum, total	NA	NA															
MET	Arsenic	17	UET	4.9E-2	2.2E-2	3.4E-2	0.3	0.4	0.4	0.2	0.3	0.3	0.1	0.2	0.2	0.1	0.1	3.2
MET	Cadmium	3	UET	1.0E-2	2.0E-2	6.7E-3	5.0E-2	0.1	0.2	7.0E-2	0.1	0.6	0.3	1.7E-2	0.2	0.3	3.7E-2	11
MET	Chromium	95	UET	4.4E-2	5.1E-2	5.9E-2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.2	0.1	0.1	8.7E-2	5.6E-2
MET	Copper	86	UET	5.6E-2	4.2E-2	1.9E-2	0.2	0.2	0.2	0.2	0.2	0.3	0.4	0.2	0.1	0.2	7.7E-2	1.2
MET	Iron	NA	NA															
MET	Lead	127	UET	0.2	1.0E-1	3.0E-2	0.3	0.2	0.3	0.2	0.3	0.2	0.2	0.2	0.2	0.2	0.1	8.0
MET	Manganese	1000	UET	5.7E-2	7.3E-2	2.4E-2	1.0	0.6	1.1	0.9	1.1	0.4	0.5	0.6	0.3	0.2	0.2	7.6E-2
MET	Nickel	43	UET	0.1	8.4E-2	0.1	0.5	0.5	0.5	0.5	0.6	0.5	0.4	0.4	0.3	0.2	0.2	0.4
MET	Silver	4.5	UET	1.1	45	4.4E-2	0.5	0.3	0.5	0.3	0.3	2.7	5.6	0.2	5.5	1.1	0.9	6.4E-2
MET	Zinc	520	UET	0.1	4.8E-2	2.1E-2	0.3	0.3	0.3	0.3	0.3	0.5	0.3	0.1	0.2	0.2	8.0E-2	42
MET	SEM-AVS	5	EPA	0.2	0.1	-4.6E-2	0.5	-2.9E+0	0.3	-3.3E+1	-2.1E-1	157	-1.9E+0	-5.9E-1	-1.8E+0	0.4	5.3E-2	54
PAH	1-Methylnaphthalene	NA	NA															
PAH	1-Methylphenanthrene	NA	NA															
PAH	2,3,5 Trimethylnaphthalene	NA	NA															
PAH	2,6 Dimethylnaphthalene	NA	NA															
PAH	2-Methylnaphthalene	670	ER-M	4.2E-3	1.4E-2	3.9E-3	1.6E-2	1.4E-2	3.7E-2	1.1E-2	1.3E-2	9.1E-3	1.9E-2	4.8E-3	3.7E-3	1.3E-2	3.6E-3	2.7E-3
PAH	Acenaphthene	290	UET	6.6E-3	0.1	9.0E-3	2.9E-2	4.5E-2	8.6E-2	2.4E-2	1.3E-2	0.1	0.1	1.7E-2	5.5E-2	0.3	4.5E-2	3.0E-2
PAH	Acenaphthylene	160	UET	1.8E-2	1.8E-2	1.6E-2	5.2E-2	0.2	0.2	4.4E-2	3.4E-2	0.1	4.7E-2	3.0E-2	2.7E-2	9.4E-2	1.3E-2	1.4E-2
PAH	Anthracene	260	UET	3.3E-2	0.2	1.0E-2	3.5E-2	0.4	6.2E-2	3.8E-2	5.0E-2	0.2	0.2	3.0E-2	6.2E-2	1.0	5.8E-2	9.6E-2
PAH	Benzo(a)anthracene	500	UET	6.0E-2	0.5	3.0E-3	0.1	1.7	0.2	0.1	0.2	0.4	0.5	8.0E-2	0.2	2.8	0.2	0.1
PAH	Benzo[a]pyrene	700	UET	5.3E-2	0.3	3.7E-3	8.9E-2	0.8	0.1	8.7E-2	0.1	0.3	0.4	6.4E-2	0.1	2.3	0.1	8.6E-2
PAH	Benzo[b]fluoranthene	9900	AET-H	3.4E-3	2.3E-2	1.7E-4	7.4E-3	6.8E-2	1.1E-2	7.0E-3	1.0E-2	2.9E-2	4.4E-2	4.3E-3	9.8E-3	0.2	9.9E-3	7.8E-3
PAH	Benzo[e]pyrene	NA	NA															
PAH	Benzo[ghi]perylene	300	UET	0.1	0.5	8.7E-3	0.2	0.9	0.3	0.2	0.3	0.4	0.7	0.1	0.2	3.0	0.2	0.1
PAH	Benzo[k]fluoranthene	13400	UET	2.2E-3	1.4E-2	1.2E-4	4.7E-3	4.4E-2	6.8E-3	3.9E-3	5.7E-3	1.6E-2	2.2E-2	2.8E-3	5.4E-3	9.0E-2	5.2E-3	4.6E-3
PAH	Biphenyl	110000	SQAL	4.7E-5	4.6E-5	3.6E-5	4.3E-6	2.2E-6	1.3E-5	4.7E-6	4.6E-6	3.3E-6	1.0E-5	8.6E-6	6.6E-6	2.2E-5	1.1E-5	1.6E-5
PAH	Chrysene	800	UET	4.3E-2	0.3	2.5E-3	8.9E-2	0.9	0.1	8.3E-2	0.1	0.3	0.4	5.5E-2	0.1	1.8	0.1	0.1
PAH	Dibenzothiophene	NA	NA															
PAH	Dibenz[a,h]anthracene	100	UET	0.2	1.0	2.6E-2	0.3	2.2	0.5	0.3	0.4	0.7	1.0	0.1	0.3	4.7	0.3	0.2
PAH	Fluoranthene	1500	UET	5.8E-2	0.2	1.1E-3	6.7E-2	1.4	0.1	6.6E-2	0.1	0.3	0.3	4.7E-2	0.1	1.3	0.1	0.2
PAH	Fluorene	300	UET	9.3E-3	9.7E-2	8.7E-3	2.5E-2	0.1	4.3E-2	2.8E-2	3.7E-2	0.1	0.2	1.6E-2	6.0E-2	0.2	3.3E-2	5.7E-2
PAH	Indeno[1,2,3-cd]pyrene	330	UET	9.4E-2	0.5	7.9E-3	0.2	1.1	0.3	0.2	0.2	0.5	0.6	0.1	0.2	3.3	0.2	0.1
PAH	Naphthalene	600	UET	4.7E-3	2.0E-2	4.3E-3	1.6E-2	1.3E-2	4.2E-2	8.8E-3	1.1E-2	1.2E-2	2.2E-2	4.5E-3	4.5E-3	2.5E-2	5.8E-3	3.7E-3
PAH	Perylene	NA	NA															
PAH	Phenanthrene	800	UET	4.1E-2	0.3	3.3E-3	4.1E-2	0.7	7.0E-2	4.3E-2	5.6E-2	9.8E-2	0.2	2.3E-2	7.1E-2	1.0	6.9E-2	0.3
PAH	Pyrene	1000	UET	7.8E-2	0.3	1.3E-3	9.7E-2	1.5	0.2	9.4E-2	0.1	0.4	0.4	6.4E-2	0.1	1.4	0.2	0.3
PAH	Total LMW (L) PAHs	5300	UET	1.0E-2	6.7E-2	3.4E-3	1.6E-2	0.1	3.5E-2	1.5E-2	1.8E-2	4.5E-2	5.7E-2	8.7E-3	2.2E-2	0.2	1.9E-2	4.8E-2
PAH	Total HMW (H) PAHs	6500	UET	4.4E-2	0.2	1.8E-3	6.3E-2	0.9	0.1	6.2E-2	9.2E-2	0.2	0.3	4.3E-2	8.7E-2	1.3	0.1	0.1
PAH	Total LMW+HMW PAHs	12000	UET	2.8E-2	0.1	2.5E-3	4.1E-2	0.6	7.3E-2	4.0E-2	5.8E-2	0.1	0.2	2.7E-2	5.7E-2	0.8	6.3E-2	9.3E-2
PCB	Total (Sumx2) PCBs	26	UET	0.3	4.8	0.2	0.8	1.2	1.1	1.3	0.5	2.1	5.3	0.6	5.4	33	1.5	0.4
PST	2,4'-DDD	27	ER-M	2.6E-2	2.6E-2	2.6E-2	5.6E-2	4.4E-2	5.9E-2	4.8E-2	5.2E-2	5.6E-2	4.1E-2	3.3E-2	4.1E-2	1.9	4.8E-2	2.6E-2
PST	2,4'-DDE	27	ER-M	2.1E-2	2.0E-2	2.1E-2	4.4E-2	3.4E-2	4.8E-2	3.7E-2	4.1E-2	4.4E-2	3.3E-2	2.5E-2	3.5E-2	0.3	2.0E-2	2.1E-2
PST	2,4'-DDT	27	ER-M	5.6E-2	0.2	1.2E-2	3.6E-2	2.0E-2	2.7E-2	2.2E-2	2.3E-2	2.5E-2	1.9E-2	1.4E-2	3.1E-2	1.2E-2	1.2E-2	1.2E-2
PST	4,4'-DDD	60	UET	7.0E-3	3.0E-2	7.0E-3	1.5E-2	1.2E-2	1.6E-2	1.3E-2	1.6E-2	1.5E-2	1.1E-2	1.1E-2	7.2E-3	6.8E-3	7.0E-3	7.0E-3
PST	4,4'-DDE	50	UET	8.0E-3	9.6E-2	8.0E-3	1.7E-2	1.5E-2	1.8E-2	1.5E-2	1.6E-2	1.7E-2	1.3E-2	9.8E-3	1.6E-2	0.3	3.0E-2	8.0E-3
PST	4,4'-DDT	50	UET	1.3E-2	6.6E-2	1.3E-2	2.8E-2	2.2E-2	3.0E-2	2.4E-2	2.6E-2	2.8E-2	2.2E-2	1.6E-2	1.3E-2	0.1	1.3E-2	1.3E-2
PST	Aldrin	40	UET	1.3E-2	1.3E-2	1.3E-2	2.8E-2	2.2E-2	3.0E-2	2.4E-2	2.5E-2	2.8E-2	2.1E-2	1.6E-2	1.3E-2	0.3	1.3E-2	1.3E-2
PST	alpha-BHC	1.0	PEL	0.4	0.4	0.4	0.8	0.6	0.9	0.7	0.7	0.8	0.6	0.5	0.4	0.9	0.4	0.4
PST	alpha-Chlordane	4.8	PEL	0.1	9.2	0.1	0.5	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.1	0.2	0.1	0.1
PST	beta-BHC	1.0	PEL	2.5	9264	0.5	298	0.8	28	4.1	0.9	1.0	1.4	0.8	0.5	2.0	0.5	0.7
PST	delta-BHC	1.0	PEL	0.5	0.5	0.5	1.0	0.8	1.1	0.9	0.9	1.0	0.8	0.6	0.5	0.5	0.5	0.5
PST	Dieldrin	300	UET	1.4E-3	2.2E-3	1.4E-3	3.0E-3	2.4E-3	3.2E-3	2.7E-3	2.8E-3	3.0E-3	2.3E-3	1.7E-3	1.5E-3	3.3E-2	1.4E-3	1.4E-3
PST	Endosulfan I	290	SQAL	4.6E-3	4.8E-3	3.7E-3	2.9E-4	3.3E-4	3.0E-4	3.2E-4	3.3E-4	2.0E-4	3.5E-4	5.9E-4	4.3E-4	2.8E-3	7.6E-4	1.5E-3
PST	Endosulfan II	140	SQAL	4.8E-3	1.4E-2	3.9E-3	3.0E-4	3.4E-4	3.2E-4	3.5E-4	3.6E-4	2.0E-4	3.5E-4	6.2E-4	4.5E-4	1.9E-3	8.0E-4	1.5E-3
PST	Endosulfan sulfate	NA	NA															
PST	Endrin	500	UET	3.0E-3	2.2E-3	3.0E-3	6.2E-3	5.0E-3	6.8E-3	5.6E-3	5.8E-3	6.2E-3	4.8E-3	3.6E-3	3.0E-3	3.0E-3	3.0E-3	3.0E-3
PST	Endrin aldehyde	NA	NA															
PST	Endrin ketone	NA	NA															
PST	gamma-BHC	9.0	UET	5.0E-2	5.0E-2	5.0E-2	0.1	8.3E-2	0.1	9.2E-2	9.7E-2	0.1	8.0E-2	6.1E-2	5.1E-2	4.9E-2	5.0E-2	5.0E-2
PST	gamma-Chlordane	4.8	PEL	7.3E-2	1.2	7.3E-2	0.2	0.1	0.2	0.1	0.1	0.2	0.1	8.8E-2	7.5E-2	7.3E-2	7.3E-2	7.3E-2
PST	Heptachlor	10	UET	6.0E-2	5.9E-2	6.0E-2	0.1	0.1	0.1	0.1	0.1	0.1	9.7E-2	7.3E-2	6.1E-2	5.9E-2	5.9E-2	6.0E-2
PST	Heptachlor epoxide	30	UET	3.1E-2	0.6	2.7E-2	5.7E-2	4.7E-2	6.0E-2	5.0E-2	5.3E-2	5.7E-2	4.3E-2	3.3E-2	2.7E-2	0.7	2.7E-2	4.0E-2
PST	Hexachlorobenzene	100	UET	8.4E-3	8.3E-3	8.4E-3	1.7E-2	1.4E-2	1.9E-2	1.6E-2	1.6E-2	1.8E-2	1.4E-2	1.0E-2	8.5E-3	8.3E-3	8.3E-3	8.4E-3
PST	Methoxychlor	190	SQAL	7.4E-2	1.4E-2	1.4E-2	2.8E-2	2.3E-2	3.1E-2	2.5E-2	2.6E-2	2.8E-2	2.2E-2	1.7E-2	1.4E-2	1.4E-2	1.4E-2	1.4E-2
PST	Mirex	800	UET	4.1E-3	4.1E-3	4.1E-3	8.6E-3	6.9E-3	9.4E-3	7.8E-3	8.0E-3	8.6E-3	6.8E-3	5.0E-3	4.3E-3	4.3E-3	4.1E-3	4.1E-3
PST	Toxaphene	NA	NA															

LMW PAH = sum of 7 2-ring & 3-ring PAHs included in NOAA ER-L/ER-M benchmarks (Long et al. 1995);
(methylnaphthalene, acenaphthene, acenaphthylene, anthracene, fluorene, naphthalene, phenanthrene).
HMW PAH = sum of 6 4-ring and 5-ring PAHs included in NOAA ER-L/ER-M benchmarks (Long et al. 1995);
(benzo(a)anthracene, benzo(a)pyrene, chrysene, dibenz(a,h)anthracene, fluoranthene, pyrene).
Total PAHs - sum of LMW & HMW PAHs; Total PCBs - Sum of individual PCB congeners x 2.
NA = benchmark not available.
Hazard Quotient = concentration(Appendix A-1-1)/benchmark(Table 2.1-1).

Appendix A-2-2. Hazard Quotients for pore water concentrations of chemicals for the Indian Head TIE investigation.

Class	Analyte	Benchmark	Benchmark Source	IH-01	IH-02	IH-03	IH-04	IH-05	IH-06	IH-07	IH-08	IH-09	IH-10	IH-11	IH-12	IH-13	IH-14	IH-15
MET	Aluminum, total	750	WQC-FA	5.5	0.5			4.8E-2	6.4E-2		6.1E-2		0.1	3.6E-2	1.3	4.8E-2		1.2
MET	Arsenic	360	WQC-FA	2.2E-2	4.7E-3			4.7E-3	4.7E-3		4.7E-3		4.7E-3	1.6E-2	4.7E-3	4.7E-3		8.8E-2
MET	Cadmium	3.9	WQC-FA	0.4	6.4E-2			5.1E-2	5.1E-2		5.1E-2		5.1E-2	5.1E-2	0.1	5.1E-2		2.7
MET	Chromium	16	WQC-FA	1.0	0.4			0.4	0.5		0.6		0.3	0.7	0.6	0.4		0.4
MET	Copper	18	WQC-FA	3.3	0.5			7.2E-2	0.1		4.7E-2		8.3E-2	0.3	0.3	0.1		2.4
MET	Iron	NA	NA															
MET	Lead	83	WQC-FA	1.7	0.1			1.6E-2	2.5E-2		5.5E-2		1.4E-2	7.8E-2	8.3E-2	0.1		1.9
MET	Manganese	1000	WQC-FA	2.4	2.8			7.5	19		24		3.0	23	3.1	6.2		0.8
MET	Nickel	1400	WQC-FA	1.4E-2	3.4E-3			1.7E-3	1.7E-3		3.0E-3		1.7E-3	2.8E-3	8.3E-3	3.1E-3		1.9E-3
MET	Silver	4.1	WQC-FA	8.1	10			0.5	0.9		1.1		0.6	1.2	1.5	0.5		0.5
MET	Zinc	120	WQC-FA	5.1	0.3			0.2	0.2		7.2E-2		7.2E-2	7.2E-2	0.5	7.2E-2		208
MET	SEM-AVS	NA	NA															
PAH	1-Methylnaphthalene	NA	NA															
PAH	1-Methylphenanthrene	NA	NA															
PAH	2,3,5 Trimethylnaphthalene	NA	NA															
PAH	2,6 Dimethylnaphthalene	NA	NA															
PAH	2-Methylnaphthalene	300	WQC-SA	2.2E-4	7.8E-4	1.6E-4	2.6E-5	3.2E-5	5.8E-5	2.3E-5	2.5E-5	9.7E-6	4.6E-5	2.6E-5	1.8E-5	2.8E-4	3.1E-5	4.4E-5
PAH	Acenaphthene	1700	WQC-FA	2.9E-5	5.6E-4	3.2E-5	3.9E-6	8.5E-6	1.1E-5	4.2E-6	2.2E-6	1.2E-5	2.8E-5	7.8E-6	2.2E-5	5.0E-4	3.3E-5	4.1E-5
PAH	Acenaphthylene	300	WQC-SA	1.8E-4	2.0E-4	1.4E-4	1.6E-5	8.3E-5	4.8E-5	1.8E-5	1.3E-5	2.9E-5	2.2E-5	3.3E-5	2.5E-5	3.8E-4	2.3E-5	4.5E-5
PAH	Anthracene	300	WQC-SA	1.8E-4	1.2E-3	4.4E-5	5.7E-6	8.8E-5	9.9E-6	8.1E-6	1.0E-5	2.1E-5	4.8E-5	1.8E-5	3.0E-5	2.2E-3	5.2E-5	1.6E-4
PAH	Benzo(a)anthracene	300	WQC-SA	4.7E-5	4.2E-4	1.9E-6	2.5E-6	5.5E-5	4.0E-6	3.3E-6	4.4E-6	6.9E-6	1.7E-5	6.6E-6	1.1E-5	8.6E-4	2.5E-5	3.2E-5
PAH	Benzo[a]pyrene	300	WQC-SA	2.3E-5	1.3E-4	1.3E-6	1.2E-6	1.4E-5	1.8E-6	1.5E-6	2.1E-6	2.7E-6	7.8E-6	2.9E-6	4.1E-6	3.9E-4	8.9E-6	1.2E-5
PAH	Benzo[b]fluoranthene	300	WQC-SA	1.7E-5	1.2E-4	6.9E-7	1.1E-6	1.4E-5	1.6E-6	1.3E-6	1.8E-6	3.0E-6	1.0E-5	2.3E-6	4.4E-6	3.3E-4	8.2E-6	1.2E-5
PAH	Benzo[e]pyrene	NA	NA															
PAH	Benzo[ghi]perylene	300	WQC-SA	5.5E-6	2.4E-5	3.4E-7	2.8E-7	1.9E-6	4.1E-7	3.4E-7	4.7E-7	3.9E-7	1.5E-6	7.2E-7	8.2E-7	5.8E-5	1.7E-6	2.1E-6
PAH	Benzo[k]fluoranthene	1.1	estimated	7.8E-3	5.4E-2	2.7E-4	1.5E-5	2.8E-4	2.1E-5	2.0E-5	2.7E-5	2.4E-5	1.6E-4	1.1E-4	1.6E-4	4.8E-2	5.0E-4	1.6E-3
PAH	Biphenyl	1407	estimated	8.9E-5	8.9E-5	5.4E-5	2.4E-7	1.7E-7	6.9E-7	3.4E-7	3.2E-7	1.2E-7	8.5E-7	1.7E-6	1.1E-6	1.6E-5	3.4E-6	9.3E-6
PAH	Chrysene	300	WQC-SA	5.3E-5	3.9E-4	2.5E-6	3.4E-6	4.7E-5	5.0E-6	4.0E-6	5.6E-6	7.9E-6	2.5E-5	7.2E-6	1.2E-5	8.6E-4	2.5E-5	4.8E-5
PAH	Dibenzothiophene	NA	NA															
PAH	Dibenz[a,h]anthracene	300	WQC-SA	2.8E-6	1.7E-5	3.5E-7	1.4E-7	1.5E-6	2.5E-7	1.8E-7	2.5E-7	2.2E-7	7.2E-7	2.4E-7	3.7E-7	3.1E-5	9.3E-7	1.1E-6
PAH	Fluoranthene	3980	WQC-FA	3.8E-5	1.5E-4	5.6E-7	1.3E-6	3.9E-5	2.2E-6	1.7E-6	2.4E-6	3.8E-6	8.7E-6	3.2E-6	6.3E-6	3.3E-4	1.3E-5	4.9E-5
PAH	Fluorene	300	WQC-SA	1.3E-4	1.4E-3	9.5E-5	1.0E-5	5.8E-5	1.7E-5	1.5E-5	1.8E-5	3.1E-5	9.9E-5	2.3E-5	7.4E-5	1.2E-3	7.5E-5	2.4E-4
PAH	Indeno[1,2,3-cd]pyrene	300	WQC-SA	5.6E-6	3.0E-5	3.8E-7	3.1E-7	2.8E-6	4.5E-7	3.6E-7	5.2E-7	5.5E-7	1.7E-6	7.3E-7	9.5E-7	7.8E-5	2.0E-6	2.4E-6
PAH	Naphthalene	2300	WQC-FA	1.1E-4	5.1E-4	8.5E-5	1.2E-5	1.3E-5	3.0E-5	8.3E-6	9.5E-6	6.0E-6	2.4E-5	1.2E-5	9.9E-6	2.4E-4	2.4E-5	2.8E-5
PAH	Perylene	NA	NA															
PAH	Phenanthrene	30	WQC-FA	6.9E-3	4.6E-2	4.4E-4	2.1E-4	4.6E-3	3.5E-4	2.8E-4	3.5E-4	3.3E-4	1.2E-3	4.0E-4	1.1E-3	6.4E-2	1.9E-3	1.3E-2
PAH	Pyrene	300	WQC-SA	4.6E-4	1.7E-3	6.2E-6	1.7E-5	3.8E-4	3.0E-5	2.2E-5	3.0E-5	4.3E-5	1.1E-4	4.0E-5	7.5E-5	3.3E-3	1.6E-4	4.6E-4
PAH	Total LMW (L) PAHs	300	WQC-SA	2.4E-3	1.5E-2	1.3E-3	1.9E-4	8.7E-4	4.6E-4	1.8E-4	1.9E-4	2.4E-4	6.8E-4	2.7E-4	4.6E-4	1.5E-2	7.4E-4	2.3E-3
PAH	Total HMW (H) PAHs	300	WQC-SA	1.1E-3	4.7E-3	2.0E-5	4.2E-5	1.0E-3	7.0E-5	5.3E-5	7.4E-5	1.1E-4	2.8E-4	1.0E-4	1.9E-4	9.7E-3	3.9E-4	1.2E-3
PAH	Total LMW+HMW PAHs	300	WQC-SA	3.5E-3	1.5E-2	2.0E-4	1.2E-4	2.3E-3	2.1E-4	1.5E-4	2.1E-4	3.0E-4	8.0E-4	2.8E-4	5.1E-4	3.1E-2	1.0E-3	2.9E-3
PCB	Total (Sumx2) PCBs	2.0	WQC-FA	3.0E-4	4.6E-3	1.5E-4	2.2E-5	4.7E-5	2.8E-5	4.5E-5	1.8E-5	3.9E-5	2.2E-4	6.2E-5	4.5E-4	1.2E-2	2.3E-4	1.0E-4
PST	2,4'-DDD	2.7E-3	estimated	9.0E-2	9.7E-2	5.9E-2	1.8E-4	2.8E-4	1.8E-4	2.5E-4	2.4E-4	8.0E-5	2.9E-4	1.3E-3	1.2E-3	1.0	4.6E-3	8.9E-3
PST	2,4'-DDE	6.1E-4	estimated	7.2E-2	7.7E-2	4.7E-2	1.4E-4	2.2E-4	1.5E-4	1.9E-4	1.9E-4	6.4E-5	2.4E-4	9.9E-4	1.0E-3	0.2	2.0E-3	7.1E-3
PST	2,4'-DDT	6.1E-4	estimated	0.2	0.9	2.7E-2	1.1E-4	1.2E-4	8.1E-5	1.1E-4	1.1E-4	3.6E-5	1.4E-4	5.7E-4	8.9E-4	6.4E-3	1.1E-3	4.1E-3
PST	4,4'-DDD	0.6	WQC-FA	1.3E-4	5.9E-4	1.1E-4	8.3E-6	9.3E-6	8.8E-6	9.5E-6	1.1E-5	5.6E-6	9.7E-6	2.1E-5	1.2E-5	5.1E-5	2.2E-5	4.1E-5
PST	4,4'-DDE	1050	WQC-FA	1.6E-8	2.0E-7	1.3E-8	1.0E-9	1.3E-9	1.1E-9	1.2E-9	1.2E-9	6.8E-10	1.2E-9	2.1E-9	3.0E-9	2.7E-7	1.0E-8	5.0E-9
PST	4,4'-DDT	1.1	WQC-FA	2.5E-5	1.3E-4	2.0E-5	1.6E-6	1.8E-6	1.7E-6	1.8E-6	1.8E-6	1.1E-6	1.9E-6	3.3E-6	2.3E-6	1.1E-4	4.2E-6	7.9E-6
PST	Aldrin	3.0	WQC-FA	1.3E-5	1.4E-5	1.1E-5	8.5E-7	9.3E-7	9.0E-7	9.5E-7	9.3E-7	5.7E-7	9.7E-7	1.7E-6	1.2E-6	1.0E-4	2.2E-6	4.1E-6
PST	alpha-BHC	0.02	estimated	1.3	1.5	0.9	2.6E-3	4.0E-3	2.7E-3	3.7E-3	3.5E-3	1.2E-3	4.4E-3	1.8E-2	1.1E-2	0.5	3.7E-2	0.1
PST	alpha-Chlordane	2.0E-4	estimated	0.5	35	0.3	1.6E-3	1.6E-3	1.0E-3	1.4E-3	1.4E-3	4.5E-4	1.6E-3	6.9E-3	4.2E-3	0.1	1.4E-2	5.0E-2
PST	beta-BHC	0.02	estimated	8.8	35063	1.1	1.0	5.2E-3	8.6E-2	2.2E-2	4.5E-3	1.5E-3	1.0E-2	3.2E-2	1.4E-2	1.1	4.8E-2	0.2
PST	delta-BHC	0.02	estimated	1.7	1.9	1.1	3.3E-3	5.2E-3	3.4E-3	4.8E-3	4.5E-3	1.5E-3	5.7E-3	2.3E-2	1.4E-2	0.3	4.8E-2	0.2
PST	Dieldrin	2.5	WQC-FA	1.7E-4	2.7E-4	1.4E-4	1.1E-5	1.2E-5	1.1E-5	1.2E-5	1.2E-5	7.1E-6	1.2E-5	2.2E-5	1.6E-5	1.5E-3	2.8E-5	5.3E-5
PST	Endosulfan I	0.2	WQC-FA															
PST	Endosulfan II	1.3	estimated	9.0E-3	2.7E-2	5.8E-3	1.7E-5	2.7E-5	1.8E-5	2.5E-5	2.5E-5	7.7E-6	3.0E-5	1.2E-4	7.6E-5	1.4E-3	2.5E-4	8.8E-4
PST	Endosulfan sulfate	NA	NA															
PST	Endrin	0.2	WQC-FA	1.6E-2	1.3E-2	1.3E-2	1.0E-3	1.2E-3	1.1E-3	1.2E-3	1.2E-3	6.9E-4	1.2E-3	2.1E-3	1.5E-3	6.5E-3	2.7E-3	5.2E-3
PST	Endrin aldehyde	NA	NA															
PST	Endrin ketone	NA	NA															
PST	gamma-BHC	2.0	WQC-FA	9.0E-3	9.4E-3	7.3E-3	5.7E-4	6.4E-4	6.0E-4	6.5E-4	6.4E-4	3.9E-4	6.6E-4	1.2E-3	8.4E-4	3.5E-3	1.5E-3	2.8E-3
PST	gamma-Chlordane	2.9E-4	estimated	0.3	4.5	0.2	4.9E-4	7.6E-4	5.0E-4	7.1E-4	6.5E-4	2.2E-4	8.4E-4	3.4E-3	2.1E-3	3.9E-2	7.0E-3	2.5E-2
PST	Heptachlor	0.5	WQC-FA	8.8E-5	9.0E-5	7.1E-5	5.3E-6	6.2E-6	6.1E-6	6.2E-6	6.4E-6	3.9E-6	6.4E-6	1.1E-5	8.1E-6	3.4E-5	1.4E-5	2.8E-5
PST	Heptachlor epoxide	0.5	WQC-FA	1.4E-4	2.7E-3	9.6E-5	7.6E-6	8.7E-6	7.8E-6	8.5E-6	8.6E-6	5.1E-6	8.6E-6	1.5E-5	1.1E-5	1.3E-3	1.9E-5	5.5E-5
PST	Hexachlorobenzene	6.0	WQC-FA	4.2E-5	4.4E-5	3.4E-5	2.6E-6	3.0E-6	2.8E-6	3.1E-6	3.0E-6	1.8E-6	3.2E-6	5.4E-6	3.9E-6	1.6E-5	7.0E-6	1.3E-5
PST	Methoxychlor	NA	NA															
PST	Mirex	0.0	estimated	1.4E-2	1.6E-2	9.4E-3	2.8E-5	4.3E-5	2.9E-5	4.1E-5	3.8E-5	1.2E-5	4.8E-5	2.0E-4	1.2E-4	2.3E-3	4.0E-4	1.4E-3
PST	Toxaphene	0.1	WQC-FA															
EXP	2,4-Dinitrotoluene	330	WQC-FA	0.5	0.5	0.4	3.3E-2	3.7E-2	3.5E-2	3.8E-2	3.7E-2	2.2E-2	3.8E-2	6.8E-2	4.9E-2	0.2	8.8E-2	0.2
EXP	Nitrobenzene	27000	WQC-FA	6.4E-3	6.4E-2	5.1E-3	4.0E-4	4.5E-4	4.3E-4	4.6E-4	4.5E-4	2.7E-4	4.7E-4	8.3E-4	5.9E-4	2.4E-3	1.1E-3	2.0E-3

Benchmark is for Chromium (6). Measured concentration is for total Chromium.
LMW PAH = sum of 7 2-ring & 3-ring PAHs included in NOAA ER-L/ER-M benchmarks (Long et al. 1995);
(methylnaphthalene, acenaphthene, acenaphthylene, anthracene, fluorene, naphthalene, phenanthrene).
HMW PAH = sum of 6 4-ring and 5-ring PAHs included in NOAA ER-L/ER-M benchmarks (Long et al. 1995);
(benzo(a)anthracene, benzo(a)pyrene, chrysene, dibenz(a,h)anthracene, fluoranthene, pyrene).
Total PAHs - sum of LMW & HMW PAHs; Total PCBs - Sum of individual PCB congeners x 2.
NA = benchmark not available.
Hazard Quotient for metals = concentration(Appendix A-1-2)/benchmark(Table 2.1-2).
Hazard Quotient for organics = concentration(Appendix A-1-3)/benchmark(Table 2.1-2);
if estimated benchmark used, benchmark x %TOC(Appendix A-1-1).

Appendix A-3.
Total Ammonia Nitrogen and calculated Unionized Ammonia.

Appendix A-3-1. Pore water unionized ammonia calculations for each TIE treatment by station for the Indian Head TIE study[1].

Untreated Samples

Sample ID	Total Ammonia (mg/L)	Temp (C)	Salinity (ppt)	pH (D rep-100%)	Temp (K)	I	I Rounded	pK	**Unionized Ammonia**
Spike	140.00	23.5	0	7.76	296.66	0.50	1	9.26	3.893
IH-1	2.00	23.5	0	7.34	296.66	0.50	1	9.26	0.022
IH-2	2.75	23.5	0	7.88	296.66	0.50	1	9.26	0.100
IH-5	25.00	23.5	0	8.33	296.66	0.50	1	9.26	2.402
IH-6	37.50	23.5	0	8.49	296.66	0.50	1	9.26	4.994
IH-8	35.00	23.5	0	8.57	296.66	0.50	1	9.26	5.456
IH-10	6.00	23.5	0	8.59	296.66	0.50	1	9.26	0.972
IH-11	25.00	23.5	0	8.21	296.66	0.50	1	9.26	1.865
IH-12	3.00	23.5	0	7.90	296.66	0.50	1	9.26	0.114
IH-13	10.75	23.5	0	8.26	296.66	0.50	1	9.26	0.892
IH-15	0.75	23.5	0	7.45	296.66	0.50	1	9.26	0.010
P.C.	0.00	23.5	0	7.79	296.66	0.50	1	9.26	0.000

Filtered Samples

Sample ID	Total Ammonia (mg/L)	Temp (C)	Salinity (ppt)	pH	Temp (K)	I	I Rounded	pK	**Unionized Ammonia**
Spike									
IH-1	2.00	23.5	0	8.03	296.66	0.50	1	9.26	0.101
IH-2	2.75	23.5	0	8.28	296.66	0.50	1	9.26	0.238
IH-5	25.00	23.5	0	8.63	296.66	0.50	1	9.26	4.374
IH-6	37.50	23.5	0	8.49	296.66	0.50	1	9.26	4.994
IH-8	35.00	23.5	0	8.45	296.66	0.50	1	9.26	4.301
IH-10	6.00	23.5	0	8.55	296.66	0.50	1	9.26	0.900
IH-11	25.00	23.5	0	8.46	296.66	0.50	1	9.26	3.135
IH-12	3.00	23.5	0	8.76	296.66	0.50	1	9.26	0.667
IH-13	10.75	23.5	0	8.66	296.66	0.50	1	9.26	1.990
IH-15	0.75	23.5	0	7.66	296.66	0.50	1	9.26	0.017
P.C.	0.00	23.5	0	7.75	296.66	0.50	1	9.26	0.000

C-18 Samples

Sample ID	Total Ammonia (mg/L)	Temp (C)	Salinity (ppt)	pH (D rep-100%)	Temp (K)	I	I Rounded	pK	**Unionized Ammonia**
Spike	140.00	23.5	0.0	7.7	296.66	0.50	1	9.26	3.559
IH-1	2.00	23.5	0	7.89	296.66	0.50	1	9.26	0.074
IH-2	2.75	23.5	0	8.33	296.66	0.50	1	9.26	0.264
IH-5	25.00	23.5	0	8.67	296.66	0.50	1	9.26	4.716
IH-6	37.50	23.5	0	8.55	296.66	0.50	1	9.26	5.622
IH-8	35.00	23.5	0	8.61	296.66	0.50	1	9.26	5.894
IH-10	6.00	23.5	0	8.77	296.66	0.50	1	9.26	1.359
IH-11	25.00	23.5	0	8.50	296.66	0.50	1	9.26	3.396
IH-12	3.00	23.5	0	8.75	296.66	0.50	1	9.26	0.655
IH-13	10.75	23.5	0	8.74	296.66	0.50	1	9.26	2.307
IH-15	0.75	23.5	0	7.56	296.66	0.50	1	9.26	0.013
P.C.	0.00	23.5	0	7.60	296.66	0.50	1	9.26	0.000

1 - Calculated with test temperature conditions and end-of-test vial pH readings.

Appendix A-3-1. continued.

Sodium Thiosulfate

Sample ID	Total Ammonia (mg/L)	Temp (C)	Salinity (ppt)	pH	Temp (K)	I	I Rounded	pK	**Unionized Ammonia**
Spike	140.00	23.5	0.0	7.7	296.66	0.50	1	9.26	3.110
IH-1	2.00	23.5	0	8.01	296.66	0.50	1	9.26	0.097
IH-2	2.75	23.5	0	8.35	296.66	0.50	1	9.26	0.275
IH-5	25.00	23.5	0	8.59	296.66	0.50	1	9.26	4.051
IH-6	37.50	23.5	0	8.54	296.66	0.50	1	9.26	5.513
IH-8	35.00	23.5	0	8.53	296.66	0.50	1	9.26	5.046
IH-10	6.00	23.5	0	8.74	296.66	0.50	1	9.26	1.287
IH-11	25.00	23.5	0	8.49	296.66	0.50	1	9.26	3.329
IH-12	3.00	23.5	0	8.72	296.66	0.50	1	9.26	0.621
IH-13	10.75	23.5	0		296.66	0.50	1	9.26	
IH-15	0.75	23.5	0		296.66	0.50	1	9.26	
P.C.	0.00	23.5	0	7.47	296.66	0.50	1	9.26	0.000

EDTA

Sample ID	Total Ammonia (mg/L)	Temp (C)	Salinity (ppt)	pH	Temp (K)	I	I Rounded	pK	**Unionized Ammonia**
Spike	140.00	23.5	0.0	7.7	296.66	0.50	1	9.26	3.110
IH-1	2.00	23.5	0	8.01	296.66	0.50	1	9.26	0.097
IH-2	2.75	23.5	0	8.30	296.66	0.50	1	9.26	0.248
IH-5	25.00	23.5	0	8.64	296.66	0.50	1	9.26	4.458
IH-6	37.50	23.5	0	8.61	296.66	0.50	1	9.26	6.315
IH-8	35.00	23.5	0	8.72	296.66	0.50	1	9.26	7.242
IH-10	6.00	23.5	0	8.78	296.66	0.50	1	9.26	1.383
IH-11	25.00	23.5	0	8.34	296.66	0.50	1	9.26	2.452
IH-12	3.00	23.5	0	8.82	296.66	0.50	1	9.26	0.742
IH-13	10.75	23.5	0	8.71	296.66	0.50	1	9.26	2.184
IH-15	0.75	23.5	0	7.50	296.66	0.50	1	9.26	0.012
P.C.	0.00	23.5	0	7.34	296.66	0.50	1	9.26	0.000

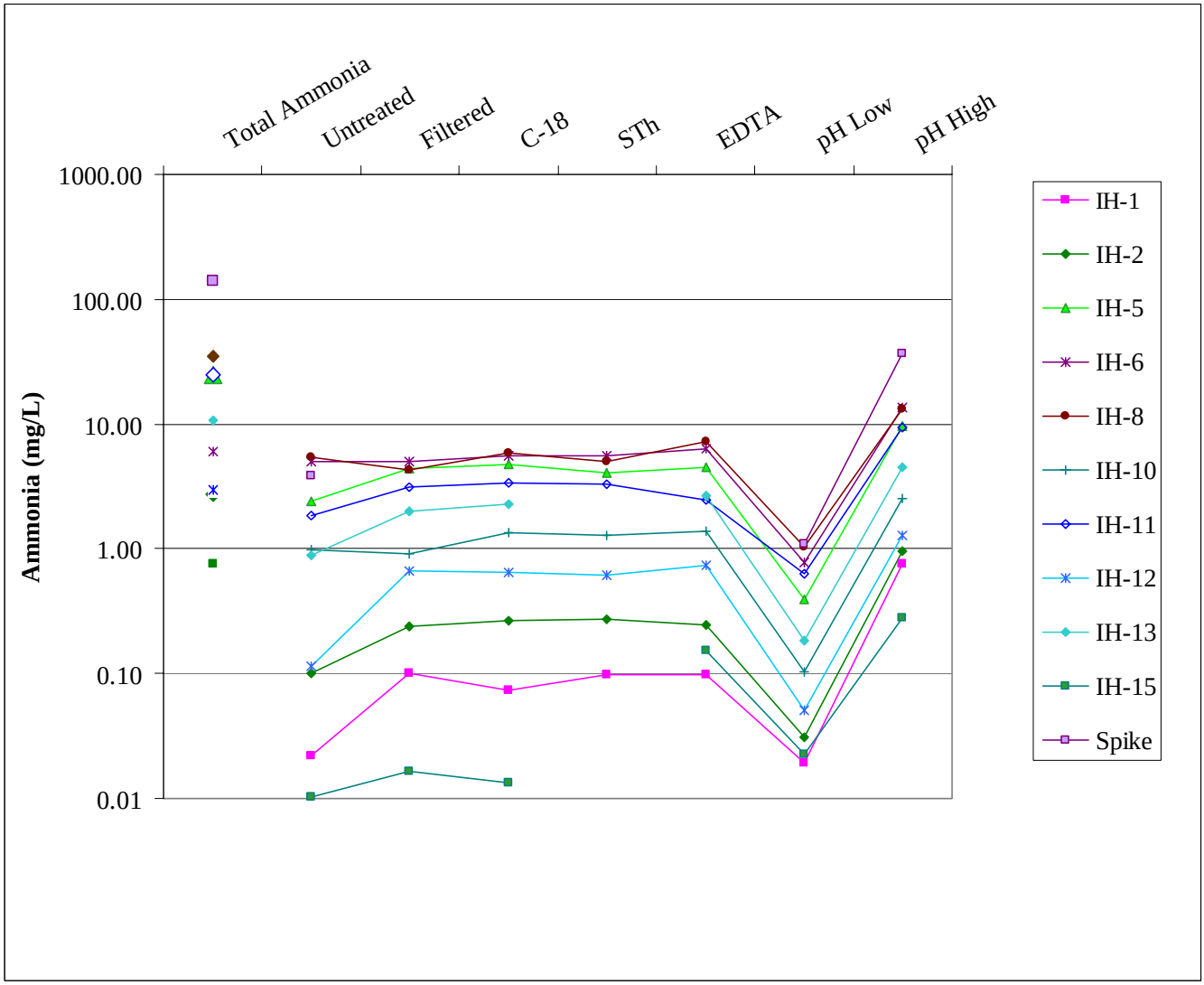
Low pH

Sample ID	Total Ammonia (mg/L)	Temp (C)	Salinity (ppt)	pH	Temp (K)	I	I Rounded	pK	**Unionized Ammonia**
Spike	140.00	23.5	0.0	7.2	296.66	0.50	1	9.26	1.094
IH-1	2.00	23.5	0	7.29	296.66	0.50	1	9.26	0.019
IH-2	2.75	23.5	0	7.36	296.66	0.50	1	9.26	0.031
IH-5	25.00	23.5	0	7.51	296.66	0.50	1	9.26	0.396
IH-6	37.50	23.5	0	7.63	296.66	0.50	1	9.26	0.779
IH-8	35.00	23.5	0	7.79	296.66	0.50	1	9.26	1.041
IH-10	6.00	23.5	0	7.55	296.66	0.50	1	9.26	0.104
IH-11	25.00	23.5	0	7.72	296.66	0.50	1	9.26	0.636
IH-12	3.00	23.5	0	7.54	296.66	0.50	1	9.26	0.051
IH-13	10.75	23.5	0	7.80	296.66	0.50	1	9.26	0.182
IH-15	0.75	23.5	0	7.23	296.66	0.50	1	9.26	0.023
P.C.	0.00	23.5	0	7.23	296.66	0.50	1	9.26	0.000

High pH

Sample ID	Total Ammonia (mg/L)	Temp (C)	Salinity (ppt)	pH	Temp (K)	I	I Rounded	pK	**Unionized Ammonia**
Spike	140.00	23.5	0.0	7.2	296.66	0.50	1	9.26	1.094
IH-1	2.00	23.5	0	7.29	296.66	0.50	1	9.26	0.019
IH-2	2.75	23.5	0	7.36	296.66	0.50	1	9.26	0.031
IH-5	25.00	23.5	0	7.51	296.66	0.50	1	9.26	0.396
IH-6	37.50	23.5	0	7.63	296.66	0.50	1	9.26	0.779
IH-8	35.00	23.5	0	7.79	296.66	0.50	1	9.26	1.041
IH-10	6.00	23.5	0	7.55	296.66	0.50	1	9.26	0.104
IH-11	25.00	23.5	0	7.72	296.66	0.50	1	9.26	0.636
IH-12	3.00	23.5	0	7.54	296.66	0.50	1	9.26	0.051
IH-13	10.75	23.5	0	7.80	296.66	0.50	1	9.26	0.182
IH-15	0.75	23.5	0	7.23	296.66	0.50	1	9.26	0.023
P.C.	0.00	23.5	0	7.23	296.66	0.50	1	9.26	0.000

Appendix A-3-2. Total Ammonia Nitrogen and calculated Unionized Ammonia Nitrogen associated with each TIE manipulation performed on Indian Head pore waters.



Note: Total Ammonia-N is presented as the first point in the data series for comparative purposes, but was not part of the TIE manipulation.
The total ammonia value was used to calculate all unionized ammonia concentrations in the TIE treatments. Changes in unionized ammonia are the result of varying pH conditions.

APPENDIX A-4.
Geotechnical analysis results.

Appendix A-4-1. Statistical summary of grain size and moisture content data for sediments collected from grabs for the Indian Head TIE investigation.

Percent content

Station	Area	Moisture Content	Coarse Gravel	Fine Gravel	Total Gravel	Coarse Sand	Medium Sand	Fine Sand	Total Sand	Fines	Total
IH-01	A2	70.0	0.0	4.7	4.7	2.4	7.7	83.8	93.9	1.4	100
IH-02	A2	71.8	0.0	4.6	4.6	4.6	25.1	59.0	88.7	6.7	100
IH-03	A1	75.9	0.0	21.8	21.8	16.9	27.2	29.9	74.0	4.2	100
IH-04	A3	24.2	0.0	0.0	0.0	0.0	0.2	4.9	5.1	95.0	100
IH-05	A1	34.5	0.0	0.0	0.0	9.0	9.4	17.4	35.8	64.2	100
IH-06	A1	8.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
IH-07	A1	27.6	0.0	0.0	0.0	0.0	0.3	5.3	5.6	94.5	100
IH-08	A1	27.0	0.0	0.0	0.0	0.0	0.3	5.6	5.9	94.1	100
IH-09	A1	20.6	0.0	0.0	0.0	0.0	1.3	8.9	10.2	89.8	100
IH-10	A1	14.9	0.0	0.0	0.0	0.0	0.0	14.1	14.1	85.9	100
IH-11	A3	41.2	0.0	0.0	0.0	0.0	0.2	18.3	18.5	81.4	100
IH-12	A3	46.5	0.0	0.0	0.0	0.0	1.7	37.3	39.0	61.2	100
IH-13	A3	57.8	0.0	0.0	0.0	0.1	0.6	45.3	46.0	54.1	100
IH-14	A3	51.3	0.0	0.0	0.0	0.2	1.0	28.6	29.8	70.3	100
IH-15	A3	66.4	0.0	10.6	10.6	12.9	14.3	50.6	77.8	11.6	100

APPENDIX A-4-2.
Particle size laboratory report.

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SAMPLE DATA SUMMARY PACKAGE

FOR Particle Size

Particle Size of Soils by ASTM D422

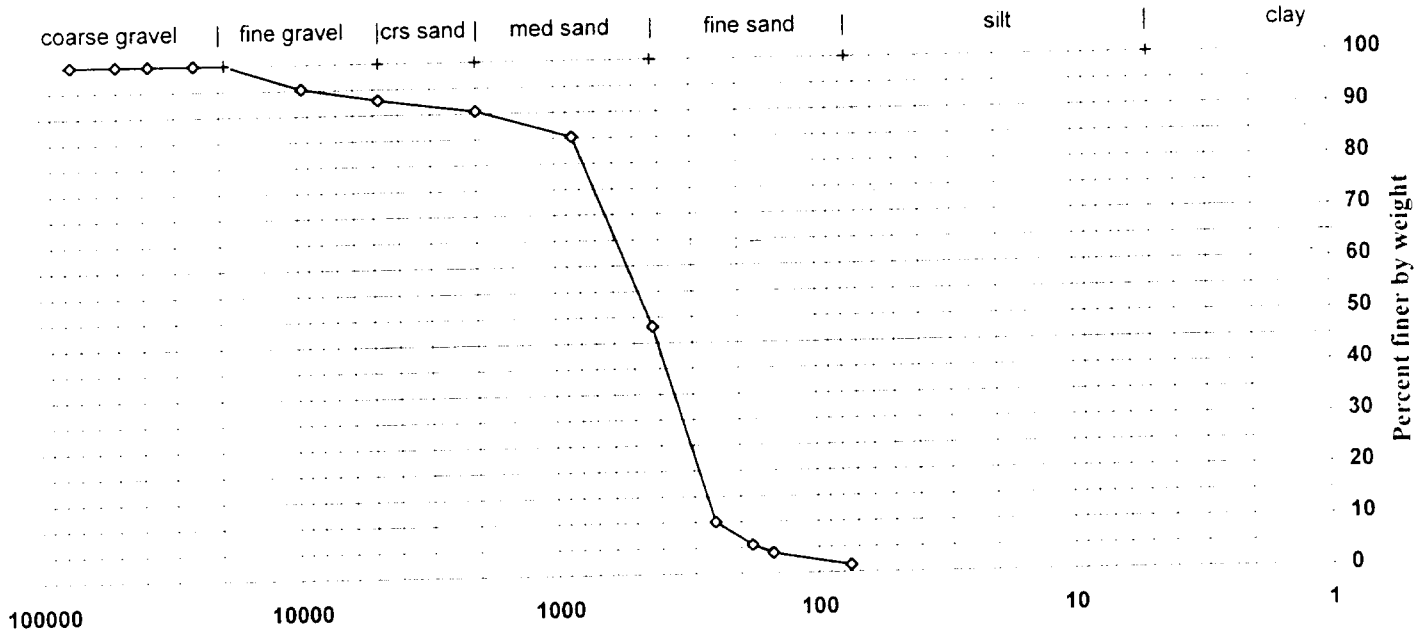
Sample preparation by: D2217

Client: STL Baltimore | **Project No.:** 20000 | **ETR(s) #:** 80372
Client Code: STLMDB | **Job No.:** SAICIH | **SDG(s):** 001402
Date Received: 30-Oct-00 | **Start Date:** 13-Nov-00 | **End Date:** 21-Nov-00

Lab ID: 435451 **Sample ID:** IH-01

Percent Solids: 78.7%
Specific Gravity: 2.65

Maximum Particle Size: 19 mm
Shape (> #10): Subangular
Hardness (> #10): Hard



Sieve size	Particle size, um	Percent finer	Incremental percent
3 inch	75000	100.0	0.0
2 inch	50000	100.0	0.0
1.5 inch	37500	100.0	0.0
1 inch	25000	100.0	0.0
3/4 inch	19000	100.0	0.0
3/8 inch	9500	95.3	4.7
#4	4750	92.9	2.4
#10	2000	90.5	2.4
#20	850	85.2	5.3
#40	425	48.2	37.0
#60	250	10.1	38.1
#80	180	5.5	4.6
#100	150	3.9	1.6
#200	75	1.4	2.5
Hydrometer	0.0	0.0	1.4
|	0.0	0.0	0.0
|	0.0	0.0	0.0
|	0.0	0.0	0.0
|	0.0	0.0	0.0
|	0.0	0.0	0.0
V	0.0	0.0	0.0

Dispersion of soil for hydrometer test by mechanical mixer with metal paddle, operated for at least one minute within a dispersion cup with 125 mls sodium hexametaphosphate

Submitted By: _____ Date: 11/22/00

Particle Size of Soils by ASTM D422

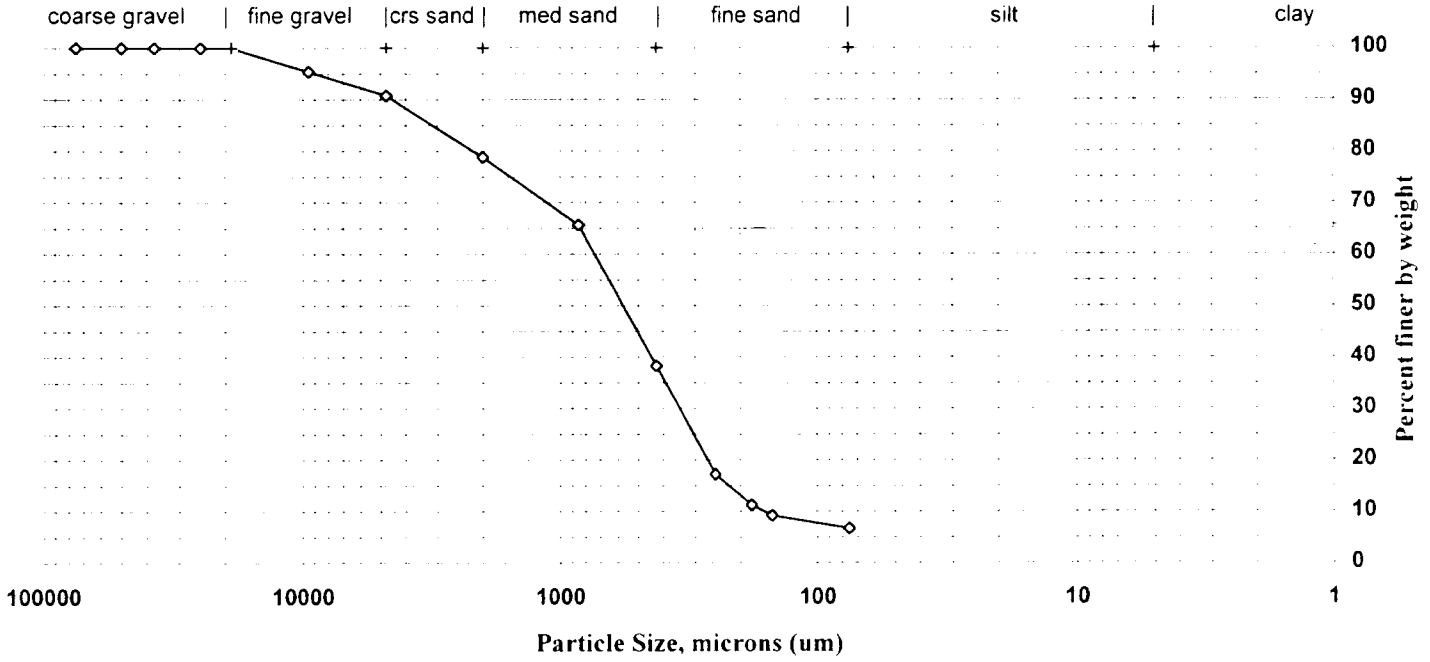
Sample preparation by: D2217

Client:	STL Baltimore	**Project No.:**	20000	**ETR(s) #:**	80372
Client Code:	STLMDB	**Job No.:**	SAICIH	**SDG(s):**	001402
Date Received:	30-Oct-00	**Start Date:**	13-Nov-00	**End Date:**	21-Nov-00

Lab ID: 435452 **Sample ID:** IH-02

Percent Solids: 81.5%
Specific Gravity: 2.65

Maximum Particle Size: 19 mm
Shape (> #10): Subangular
Hardness (> #10): Hard



Sieve size	Particle size, um	Percent finer	Incremental percent
3 inch	75000	100.0	0.0
2 inch	50000	100.0	0.0
1.5 inch	37500	100.0	0.0
1 inch	25000	100.0	0.0
3/4 inch	19000	100.0	0.0
3/8 inch	9500	95.4	4.6
#4	4750	90.8	4.6
#10	2000	78.8	12.0
#20	850	65.7	13.1
#40	425	38.3	27.4
#60	250	17.3	21.1
#80	180	11.3	6.0
#100	150	9.2	2.0
#200	75	6.7	2.5
Hydrometer	0.0	0.0	6.7
|	0.0	0.0	0.0
|	0.0	0.0	0.0
|	0.0	0.0	0.0
|	0.0	0.0	0.0
|	0.0	0.0	0.0
V	0.0	0.0	0.0

Dispersion of soil for hydrometer test by mechanical mixer with metal paddle, operated for at least one minute within a dispersion cup with 125 mls sodium hexametaphosphate

Submitted By: _____ Date: 11/22/00

Particle Size of Soils by ASTM D422

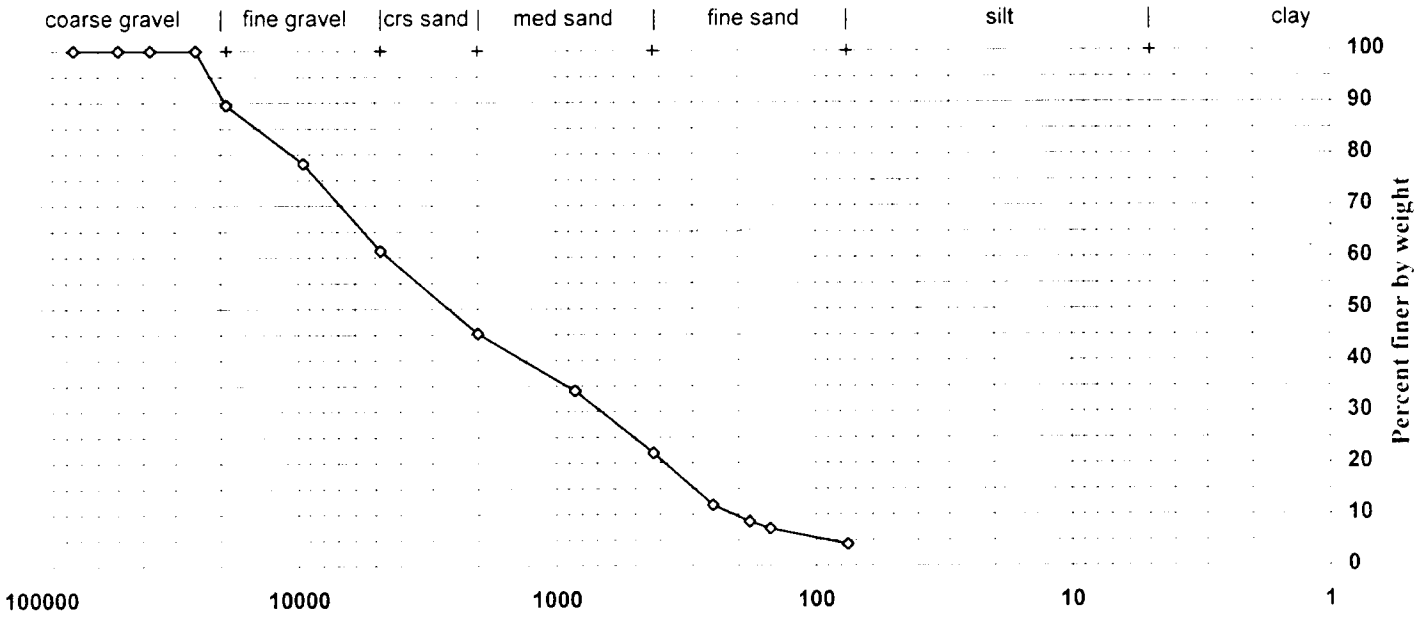
Sample preparation by: D2217

Client:	STL Baltimore	**Project No.:**	20000	**ETR(s) #:**	80372
Client Code:	STLMDB	**Job No.:**	SAICIH	**SDG(s):**	001402
Date Received:	30-Oct-00	**Start Date:**	13-Nov-00	**End Date:**	21-Nov-00

Lab ID: 435453 **Sample ID:** IH-03

Percent Solids: 87.2%
Specific Gravity: 2.65

Maximum Particle Size: 25 mm
Shape (> #10): Subrounded
Hardness (> #10): Hard



Sieve size	Particle size, um	Percent finer	Incremental percent
3 inch	75000	100.0	0.0
2 inch	50000	100.0	0.0
1.5 inch	37500	100.0	0.0
1 inch	25000	100.0	0.0
3/4 inch	19000	89.6	10.4
3/8 inch	9500	78.2	11.4
#4	4750	61.3	16.9
#10	2000	45.3	16.0
#20	850	34.0	11.2
#40	425	22.0	12.1
#60	250	11.8	10.1
#80	180	8.6	3.3
#100	150	7.2	1.4
#200	75	4.2	3.0
Hydrometer	0.0	0.0	4.2
|	0.0	0.0	0.0
|	0.0	0.0	0.0
|	0.0	0.0	0.0
|	0.0	0.0	0.0
|	0.0	0.0	0.0
V	0.0	0.0	0.0

Dispersion of soil for hydrometer test by mechanical mixer with metal paddle, operated for at least one minute within a dispersion cup with 125 mls sodium hexametaphosphate

Submitted By: Date: 11/22/00

Particle Size of Soils by ASTM D422

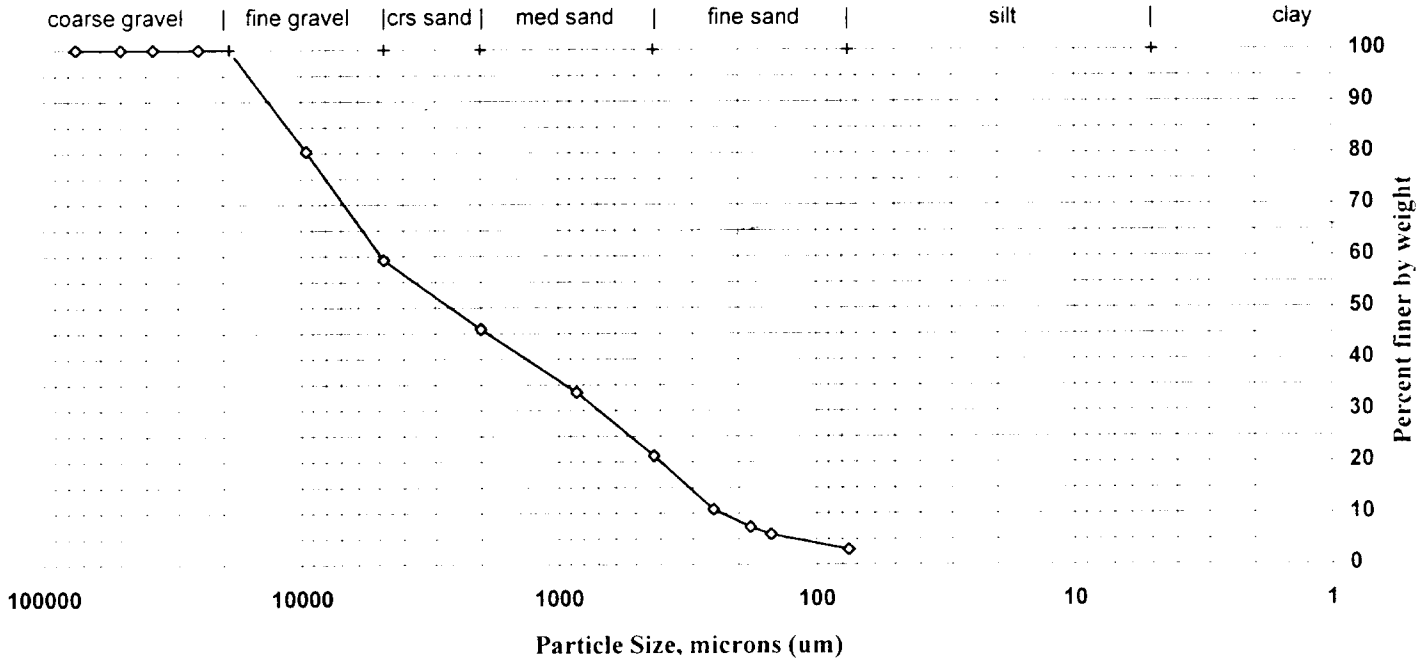
Sample preparation by: **D2217**

Client:	STL Baltimore	**Project No.:**	20000	**ETR(s) #:**	80372
Client Code:	STLMDB	**Job No.:**	SAICIH	**SDG(s):**	001402
Date Received:	30-Oct-00	**Start Date:**	13-Nov-00	**End Date:**	21-Nov-00

Lab ID: 435453DP **Sample ID:** IH-03REP

Percent Solids: 86.2%
Specific Gravity: 2.65

Maximum Particle Size: 19 mm
Shape (> #10): Subrounded
Hardness (> #10): Hard



Sieve size	Particle size, um	Percent finer	Incremental percent
3 inch	75000	100.0	0.0
2 inch	50000	100.0	0.0
1.5 inch	37500	100.0	0.0
1 inch	25000	100.0	0.0
3/4 inch	19000	100.0	0.0
3/8 inch	9500	80.3	19.7
#4	4750	59.3	21.0
#10	2000	45.9	13.4
#20	850	33.5	12.4
#40	425	21.2	12.3
#60	250	10.8	10.5
#80	180	7.4	3.4
#100	150	5.9	1.4
#200	75	3.0	3.0
Hydrometer	0.0	0.0	3.0
|	0.0	0.0	0.0
|	0.0	0.0	0.0
|	0.0	0.0	0.0
|	0.0	0.0	0.0
|	0.0	0.0	0.0
V	0.0	0.0	0.0

CS GR
FGR
CS S
MS
FS
FINES

Dispersion of soil for hydrometer test by mechanical mixer with metal paddle, operated for at least one minute within a dispersion cup with 125 mls sodium hexametaphosphate

Submitted By: **Date:** 11/22/00 STL - Burlington 80372SO.xls::Report

Particle Size of Soils by ASTM D422

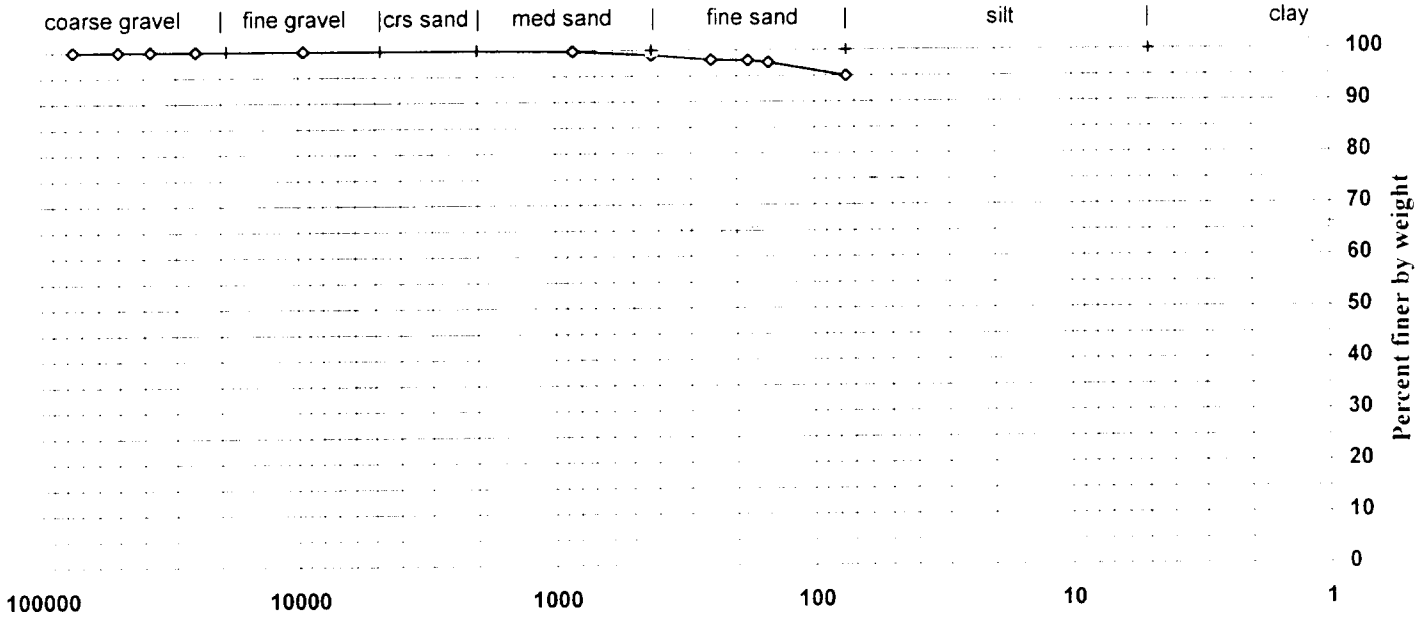
Sample preparation by: D2217

Client: STL Baltimore | **Project No.:** 20000 | **ETR(s) #:** 80372
Client Code: STLMDB | **Job No.:** SAICIH | **SDG(s):** 001402
Date Received: 30-Oct-00 | **Start Date:** 13-Nov-00 | **End Date:** 21-Nov-00

Lab ID: 435454 **Sample ID:** IH-04

Percent Solids: 25.8%
Specific Gravity: 2.65

Maximum Particle Size: Med sand
Shape (> #10): N/A
Hardness (> #10): N/A



Sieve size	Particle size, um	Percent finer	Incremental percent
3 inch	75000	100.0	0.0
2 inch	50000	100.0	0.0
1.5 inch	37500	100.0	0.0
1 inch	25000	100.0	0.0
3/4 inch	19000	100.0	0.0
3/8 inch	9500	100.0	0.0
#4	4750	100.0	0.0
#10	2000	100.0	0.0
#20	850	99.8	0.2
#40	425	99.0	0.8
#60	250	98.1	0.9
#80	180	98.0	0.1
#100	150	97.6	0.4
#200	75	95.0	2.7
Hydrometer	0.0	0.0	95.0
|	0.0	0.0	0.0
|	0.0	0.0	0.0
|	0.0	0.0	0.0
|	0.0	0.0	0.0
|	0.0	0.0	0.0
V	0.0	0.0	0.0

CS GR
FGR
CS S
MS S
FS
Fines

Dispersion of soil for hydrometer test by mechanical mixer with metal paddle, operated for at least one minute within a dispersion cup with 125 mls sodium hexametaphosphate

Submitted By: _____ **Date:** 11/22/00

Particle Size of Soils by ASTM D422

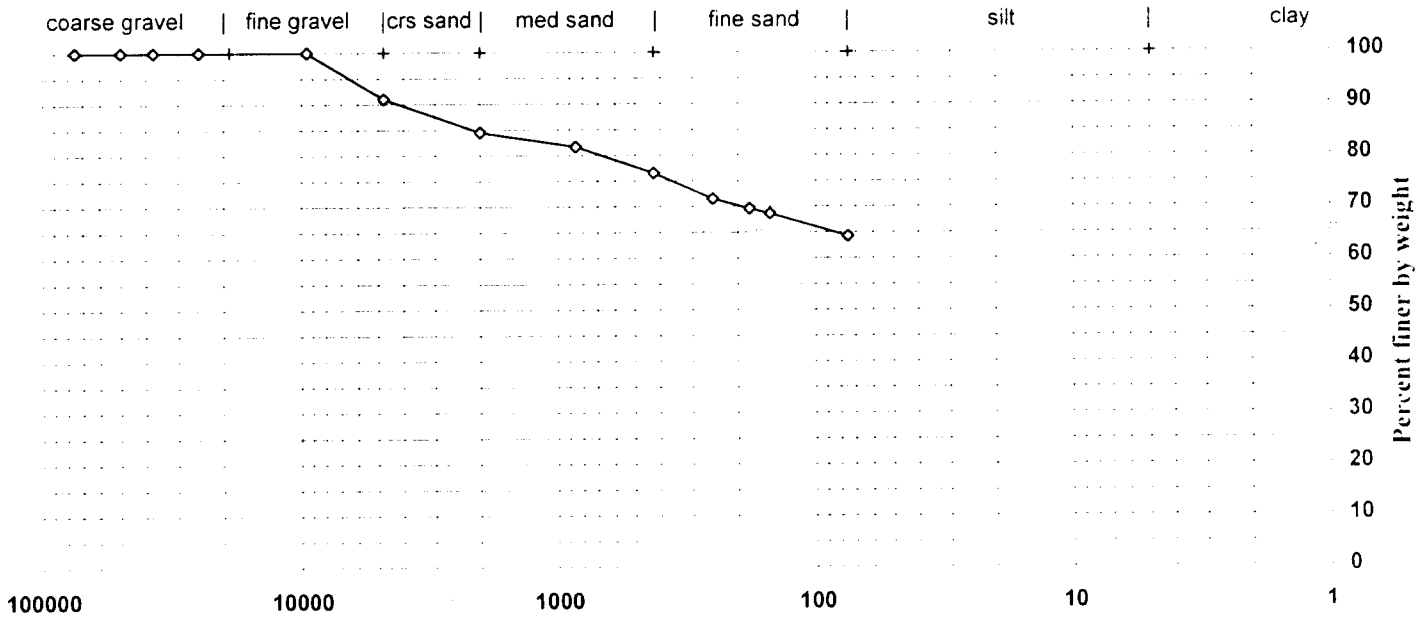
Sample preparation by: D2217

Client:	STL Baltimore	**Project No.:**	20000	**ETR(s) #:**	80372
Client Code:	STLMDB	**Job No.:**	SAICIH	**SDG(s):**	001402
Date Received:	30-Oct-00	**Start Date:**	13-Nov-00	**End Date:**	21-Nov-00

Lab ID: 435455 **Sample ID:** IH-05

Percent Solids: 33.7%
Specific Gravity: 2.65

Maximum Particle Size: 9.5 mm
Shape (> #10): Subangular
Hardness (> #10): Hard



Sieve size	Particle size, um	Percent finer	Incremental percent
3 inch	75000	100.0	0.0
2 inch	50000	100.0	0.0
1.5 inch	37500	100.0	0.0
1 inch	25000	100.0	0.0
3/4 inch	19000	100.0	0.0
3/8 inch	9500	100.0	0.0
#4	4750	91.0	9.0
#10	2000	84.5	6.5
#20	850	81.7	2.9
#40	425	76.6	5.1
#60	250	71.5	5.1
#80	180	69.6	1.9
#100	150	68.6	0.9
#200	75	64.2	4.4
Hydrometer	0.0	0.0	64.2
|	0.0	0.0	0.0
|	0.0	0.0	0.0
|	0.0	0.0	0.0
|	0.0	0.0	0.0
|	0.0	0.0	0.0
V	0.0	0.0	0.0

Cs Gr
Cs S Fs Gr
Ms
Fs
Fines

Dispersion of soil for hydrometer test by mechanical mixer with metal paddle, operated for at least one minute within a dispersion cup with 125 mls sodium hexametaphosphate

Submitted By:  **Date:** 11/22/00

Particle Size of Soils by ASTM D422

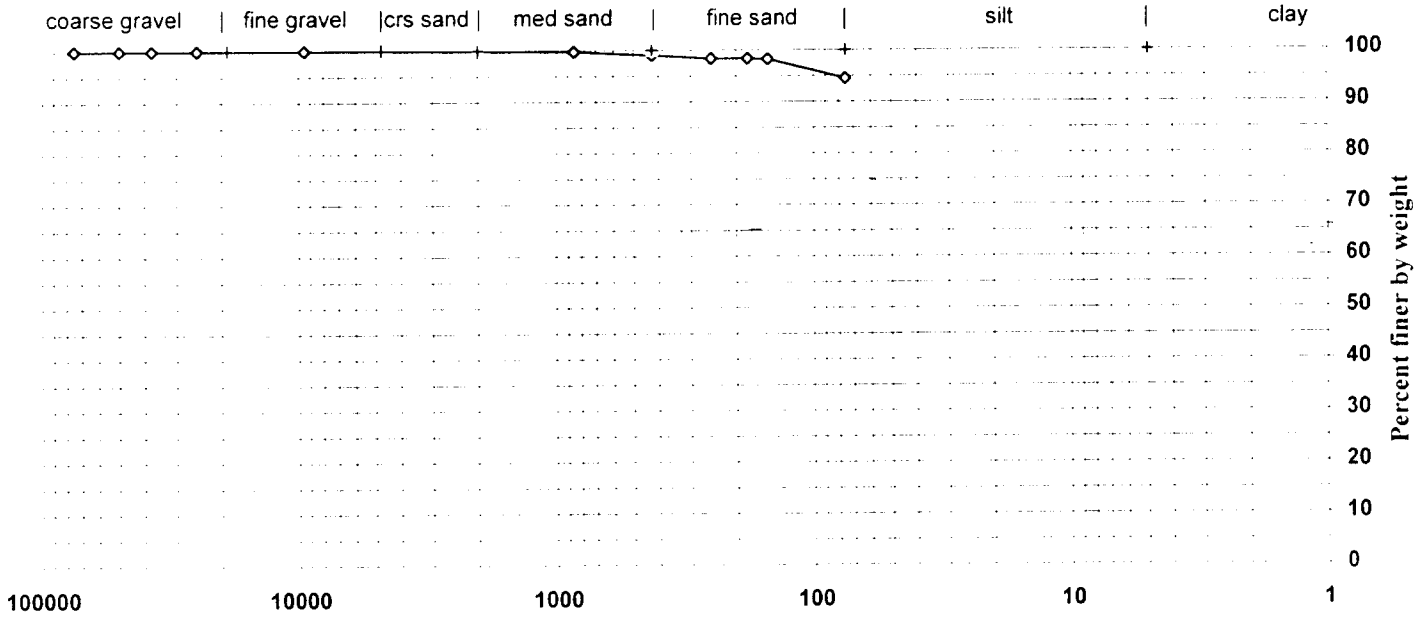
Sample preparation by: D2217

Client:	STL Baltimore	**Project No.:**	20000	**ETR(s) #:**	80372
Client Code:	STLMDB	**Job No.:**	SAICIH	**SDG(s):**	001402
Date Received:	30-Oct-00	**Start Date:**	13-Nov-00	**End Date:**	21-Nov-00

Lab ID: 435457 **Sample ID:** IH-07

Percent Solids: 29.5%
Specific Gravity: 2.65

Maximum Particle Size: Crs sand
Shape (> #10): Subangular
Hardness (> #10): Hard



Sieve size	Particle size, um	Percent finer	Incremental percent	
3 inch	75000	100.0	0.0	
2 inch	50000	100.0	0.0	Cs Gr
1.5 inch	37500	100.0	0.0	
1 inch	25000	100.0	0.0	
3/4 inch	19000	100.0	0.0	
3/8 inch	9500	100.0	0.0	Fgr
#4	4750	100.0	0.0	
#10	2000	99.9	0.1	Cs S
#20	850	99.7	0.2	
#40	425	99.0	0.7	MS
#60	250	98.4	0.7	
#80	180	98.4	0.0	FS
#100	150	98.3	0.1	
#200	75	94.5	3.8	
Hydrometer	0.0	0.0	94.5	Fines
|	0.0	0.0	0.0	
|	0.0	0.0	0.0	
|	0.0	0.0	0.0	
|	0.0	0.0	0.0	
|	0.0	0.0	0.0	
V	0.0	0.0	0.0	

Dispersion of soil for hydrometer test by mechanical mixer with metal paddle, operated for at least one minute within a dispersion cup with 125 mls sodium hexametaphosphate

Submitted By: Date: 11/22/00 STL - Burlington 80372SO.xls::Report

Particle Size of Soils by ASTM D422

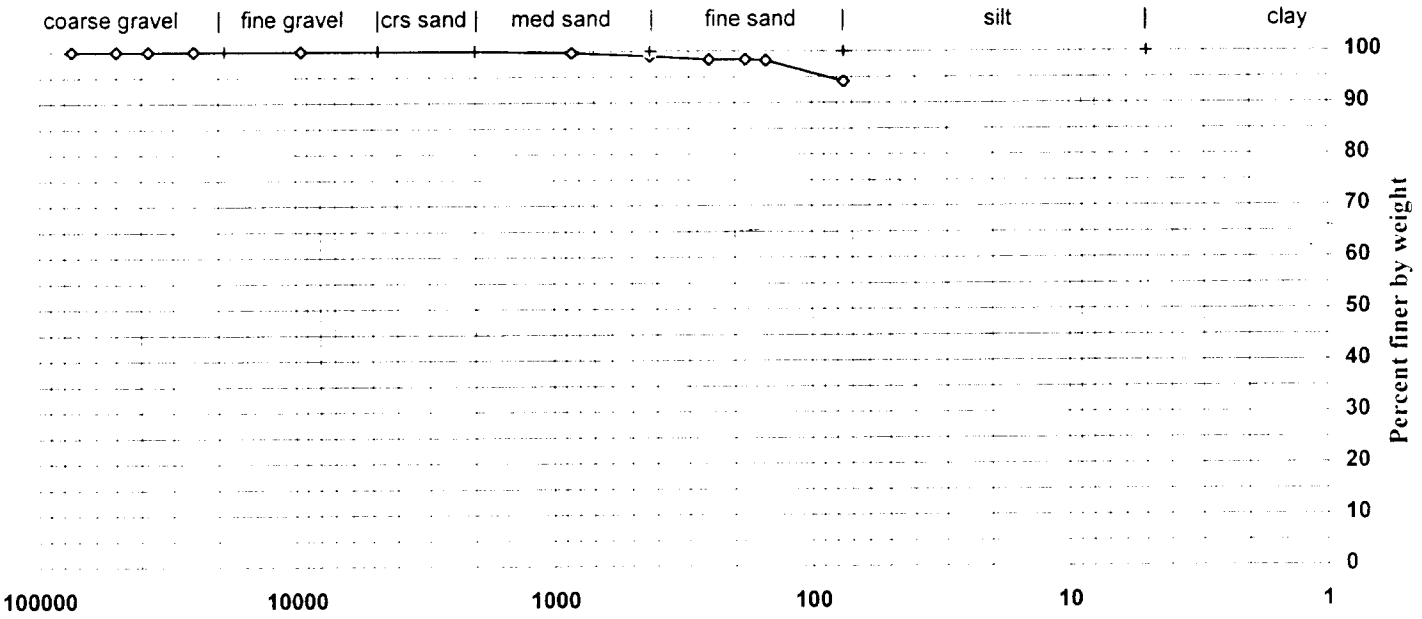
Sample preparation by: **D2217**

Client:	STL Baltimore	**Project No.:**	20000	**ETR(s) #:**	80372
Client Code:	STLMDB	**Job No.:**	SAICIH	**SDG(s):**	001402
Date Received:	30-Oct-00	**Start Date:**	13-Nov-00	**End Date:**	21-Nov-00

Lab ID: 435458 **Sample ID:** IH-08

Percent Solids: 28.6%
Specific Gravity: 2.65

Maximum Particle Size: Med sand
Shape (> #10): N/A
Hardness (> #10): N/A



Sieve size	Particle size, um	Percent finer	Incremental percent
3 inch	75000	100.0	0.0
2 inch	50000	100.0	0.0
1.5 inch	37500	100.0	0.0
1 inch	25000	100.0	0.0
3/4 inch	19000	100.0	0.0
3/8 inch	9500	100.0	0.0
#4	4750	100.0	0.0
#10	2000	100.0	0.0
#20	850	99.7	0.3
#40	425	99.1	0.6
#60	250	98.4	0.7
#80	180	98.4	0.0
#100	150	98.2	0.2
#200	75	94.1	4.1
Hydrometer	0.0	0.0	94.1
|	0.0	0.0	0.0
|	0.0	0.0	0.0
|	0.0	0.0	0.0
|	0.0	0.0	0.0
|	0.0	0.0	0.0
V	0.0	0.0	0.0

CS Gr
F Gr
CS S
M S
F S
fines

Dispersion of soil for hydrometer test by mechanical mixer with metal paddle, operated for at least one minute within a dispersion cup with 125 mls sodium hexametaphosphate

Submitted By: **Date:** 11/22/00 STL - Burlington 80372SO.xls::Report

Particle Size of Soils by ASTM D422

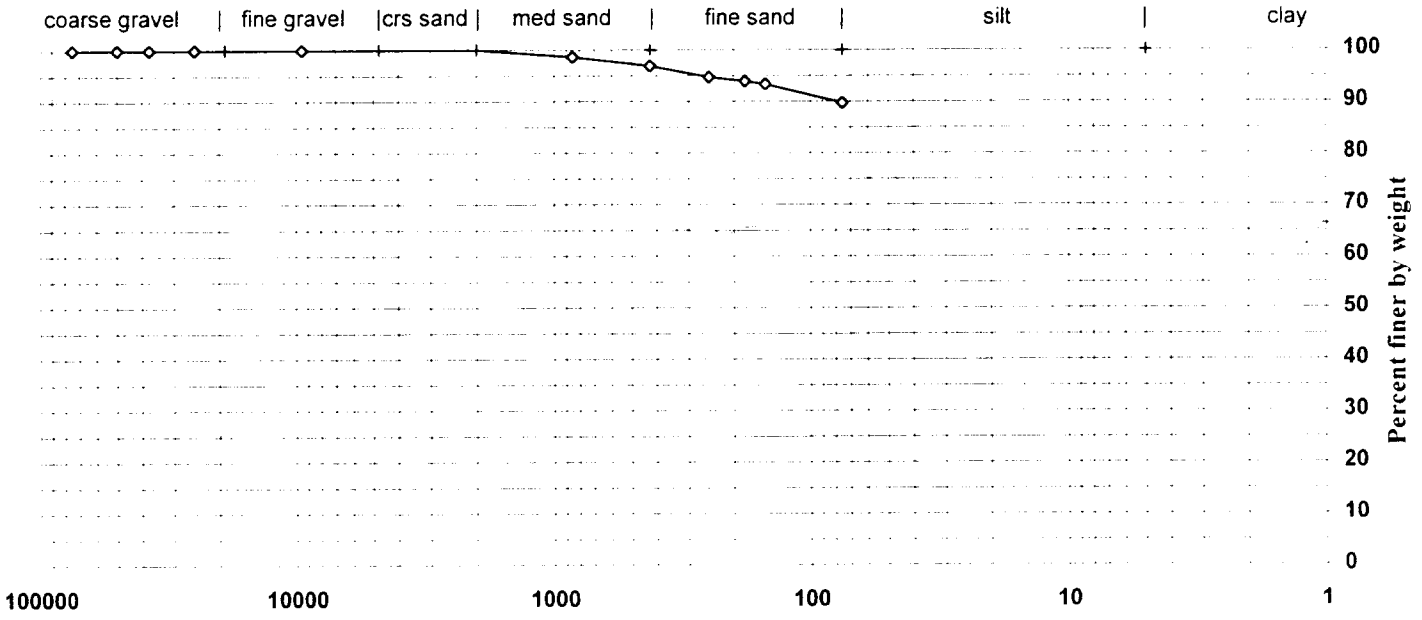
Sample preparation by: **D2217**

Client:	STL Baltimore	**Project No.:**	20000	**ETR(s) #:**	80372
Client Code:	STLMDB	**Job No.:**	SAICIH	**SDG(s):**	001402
Date Received:	30-Oct-00	**Start Date:**	13-Nov-00	**End Date:**	21-Nov-00

Lab ID: 435459 **Sample ID:** IH-09

Percent Solids: 23.3%
Specific Gravity: 2.65

Maximum Particle Size: Med sand
Shape (> #10): N/A
Hardness (> #10): N/A



Sieve size	Particle size, um	Percent finer	Incremental percent
3 inch	75000	100.0	0.0
2 inch	50000	100.0	0.0
1.5 inch	37500	100.0	0.0
1 inch	25000	100.0	0.0
3/4 inch	19000	100.0	0.0
3/8 inch	9500	100.0	0.0
#4	4750	100.0	0.0
#10	2000	100.0	0.0
#20	850	98.7	1.3
#40	425	96.9	1.7
#60	250	94.7	2.2
#80	180	93.9	0.8
#100	150	93.4	0.6
#200	75	89.8	3.6
Hydrometer	0.0	0.0	89.8
|	0.0	0.0	0.0
|	0.0	0.0	0.0
|	0.0	0.0	0.0
|	0.0	0.0	0.0
|	0.0	0.0	0.0
V	0.0	0.0	0.0

Dispersion of soil for hydrometer test by mechanical mixer with metal paddle, operated for at least one minute within a dispersion cup with 125 mls sodium hexametaphosphate

Submitted By: Date: 11/22/00

Particle Size of Soils by ASTM D422

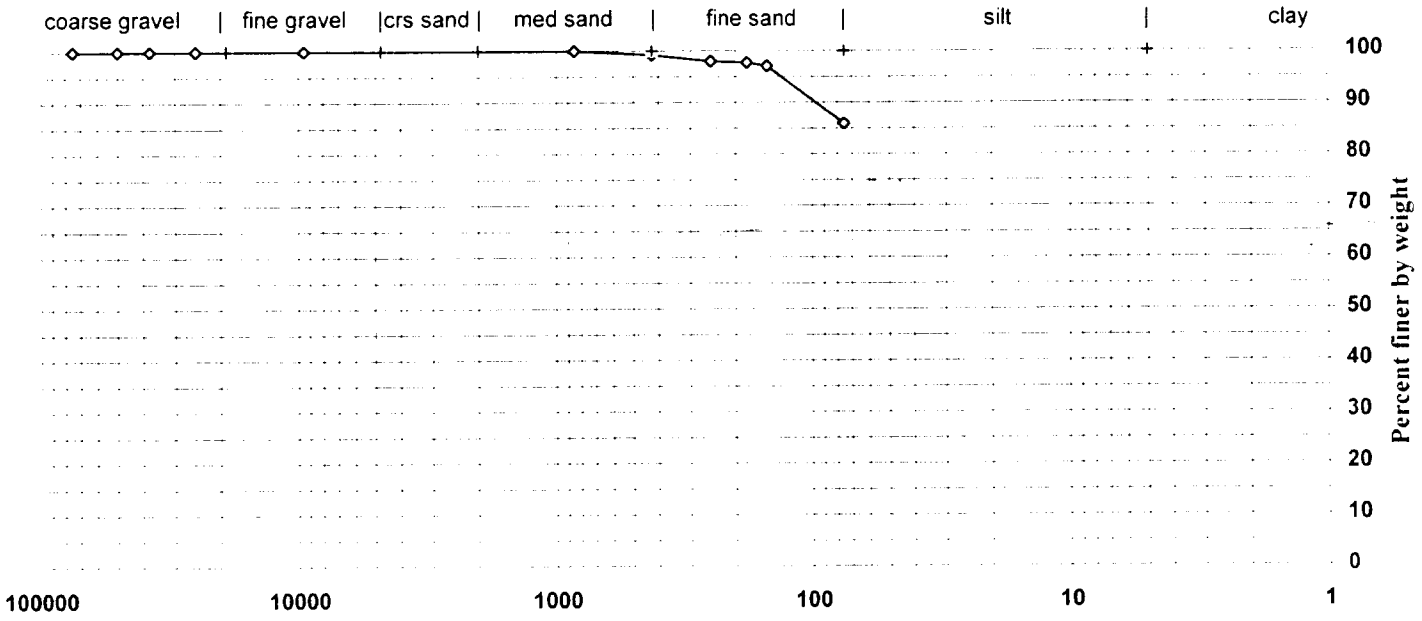
Sample preparation by: **D2217**

Client:	STL Baltimore	**Project No.:**	20000	**ETR(s) #:**	80372
Client Code:	STLMDB	**Job No.:**	SAICIH	**SDG(s):**	001402
Date Received:	30-Oct-00	**Start Date:**	13-Nov-00	**End Date:**	21-Nov-00

Lab ID: 435460 **Sample ID:** IH-10

Percent Solids: 32.6%
Specific Gravity: 2.65

Maximum Particle Size: Med sand
Shape (> #10): N/A
Hardness (> #10): N/A



Sieve size	Particle size, um	Percent finer	Incremental percent
3 inch	75000	100.0	0.0
2 inch	50000	100.0	0.0
1.5 inch	37500	100.0	0.0
1 inch	25000	100.0	0.0
3/4 inch	19000	100.0	0.0
3/8 inch	9500	100.0	0.0
#4	4750	100.0	0.0
#10	2000	100.0	0.0
#20	850	100.0	0.0
#40	425	99.2	0.8
#60	250	98.0	1.2
#80	180	97.7	0.3
#100	150	97.1	0.6
#200	75	85.9	11.2
Hydrometer	0.0	0.0	85.9
|	0.0	0.0	0.0
|	0.0	0.0	0.0
|	0.0	0.0	0.0
|	0.0	0.0	0.0
|	0.0	0.0	0.0
V	0.0	0.0	0.0

Dispersion of soil for hydrometer test by mechanical mixer with metal paddle, operated for at least one minute within a dispersion cup with 125 mls sodium hexametaphosphate

Submitted By: **Date:** 11/22/00 **STL - Burlington** **80372SO.xls::Report**

Particle Size of Soils by ASTM D422

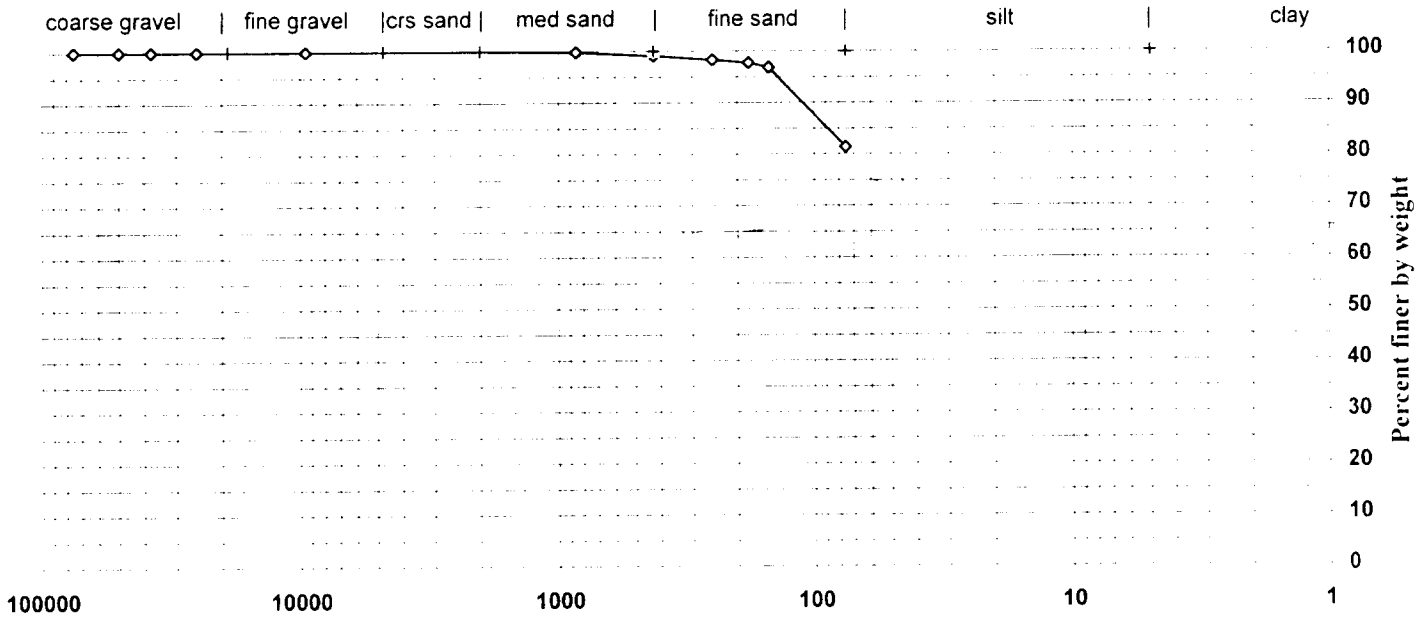
Sample preparation by: D2217

Client: STL Baltimore | **Project No.:** 20000 | **ETR(s) #:** 80372
Client Code: STLMDB | **Job No.:** SAICIH | **SDG(s):** 001402
Date Received: 30-Oct-00 | **Start Date:** 13-Nov-00 | **End Date:** 21-Nov-00

Lab ID: 435461 **Sample ID:** IH-11

Percent Solids: 46.9%
Specific Gravity: 2.65

Maximum Particle Size: Med sand
Shape (> #10): N/A
Hardness (> #10): N/A



Sieve size	Particle size, um	Percent finer	Incremental percent
3 inch	75000	100.0	0.0
2 inch	50000	100.0	0.0
1.5 inch	37500	100.0	0.0
1 inch	25000	100.0	0.0
3/4 inch	19000	100.0	0.0
3/8 inch	9500	100.0	0.0
#4	4750	100.0	0.0
#10	2000	100.0	0.0
#20	850	99.8	0.2
#40	425	99.1	0.7
#60	250	98.3	0.8
#80	180	97.7	0.5
#100	150	96.8	0.9
#200	75	81.4	15.4
Hydrometer	0.0	0.0	81.4
|	0.0	0.0	0.0
|	0.0	0.0	0.0
|	0.0	0.0	0.0
|	0.0	0.0	0.0
|	0.0	0.0	0.0
V	0.0	0.0	0.0

Dispersion of soil for hydrometer test by mechanical mixer with metal paddle, operated for at least one minute within a dispersion cup with 125 mls sodium hexametaphosphate

Submitted By: Date: 11/22/00 STL - Burlington 80372SO.xls::Report

Particle Size of Soils by ASTM D422

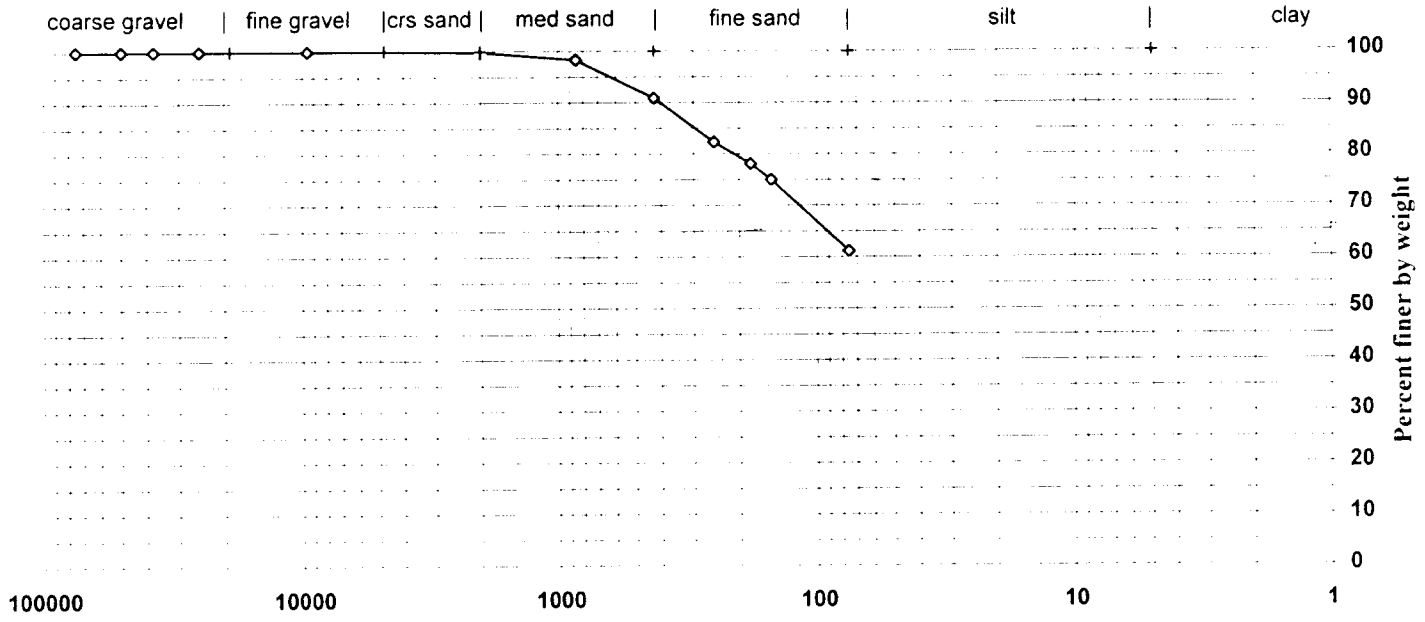
Sample preparation by: D2217

Client:	STL Baltimore	**Project No.:**	20000	**ETR(s) #:**	80372
Client Code:	STLMDB	**Job No.:**	SAICIH	**SDG(s):**	001402
Date Received:	30-Oct-00	**Start Date:**	13-Nov-00	**End Date:**	21-Nov-00

Lab ID: 435462 **Sample ID:** IH-12

Percent Solids: 51.3%
Specific Gravity: 2.65

Maximum Particle Size: Crs sand
Shape (> #10): Subangular
Hardness (> #10): Soft



Sieve size	Particle size, um	Percent finer	Incremental percent
3 inch	75000	100.0	0.0
2 inch	50000	100.0	0.0
1.5 inch	37500	100.0	0.0
1 inch	25000	100.0	0.0
3/4 inch	19000	100.0	0.0
3/8 inch	9500	100.0	0.0
#4	4750	100.0	0.0
#10	2000	99.8	0.2
#20	850	98.3	1.5
#40	425	90.9	7.5
#60	250	82.3	8.6
#80	180	78.1	4.2
#100	150	75.0	3.1
#200	75	61.2	13.9
Hydrometer	0.0	0.0	61.2
|	0.0	0.0	0.0
|	0.0	0.0	0.0
|	0.0	0.0	0.0
|	0.0	0.0	0.0
|	0.0	0.0	0.0
V	0.0	0.0	0.0

CS GR
F GR
CS S
MS
Fines

Dispersion of soil for hydrometer test by mechanical mixer with metal paddle, operated for at least one minute within a dispersion cup with 125 mls sodium hexametaphosphate

Submitted By: Date: 11/22/00 STL - Burlington 80372ASO.xls::Report

Particle Size of Soils by ASTM D422

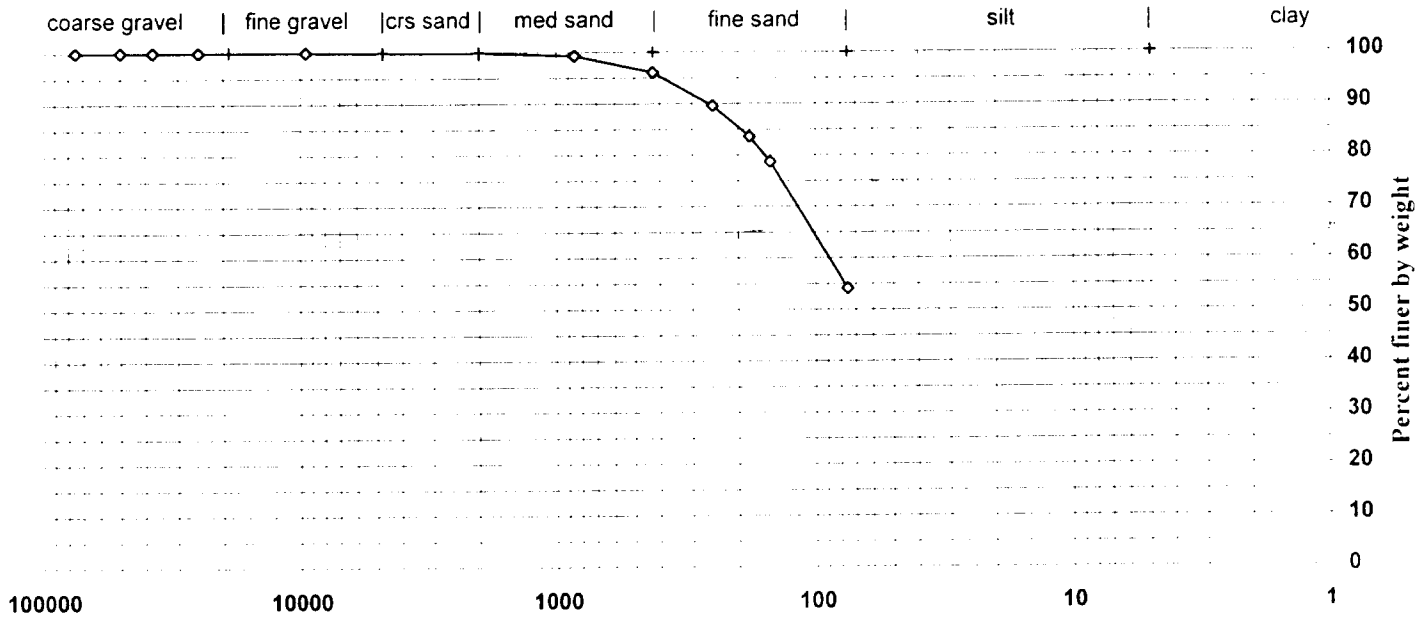
Sample preparation by: D2217

Client:	STL Baltimore	**Project No.:**	20000	**ETR(s) #:**	80372
Client Code:	STLMDB	**Job No.:**	SAICIH	**SDG(s):**	001402
Date Received:	30-Oct-00	**Start Date:**	13-Nov-00	**End Date:**	21-Nov-00

Lab ID: 435463 **Sample ID:** IH-13

Percent Solids: 65.8%
Specific Gravity: 2.65

Maximum Particle Size: 9.5 mm
Shape (> #10): Subangular
Hardness (> #10): Brittle



Sieve size	Particle size, um	Percent finer	Incremental percent
3 inch	75000	100.0	0.0
2 inch	50000	100.0	0.0
1.5 inch	37500	100.0	0.0
1 inch	25000	100.0	0.0
3/4 inch	19000	100.0	0.0
3/8 inch	9500	100.0	0.0
#4	4750	99.9	0.1
#10	2000	99.9	0.0
#20	850	99.3	0.6
#40	425	96.1	3.3
#60	250	89.6	6.5
#80	180	83.6	6.0
#100	150	78.7	4.9
#200	75	54.1	24.6
Hydrometer	0.0	0.0	54.1
|	0.0	0.0	0.0
|	0.0	0.0	0.0
|	0.0	0.0	0.0
|	0.0	0.0	0.0
|	0.0	0.0	0.0
V	0.0	0.0	0.0

Dispersion of soil for hydrometer test by mechanical mixer with metal paddle, operated for at least one minute within a dispersion cup with 125 mls sodium hexametaphosphate

Submitted By: _____ Date: 11/22/00

Particle Size of Soils by ASTM D422

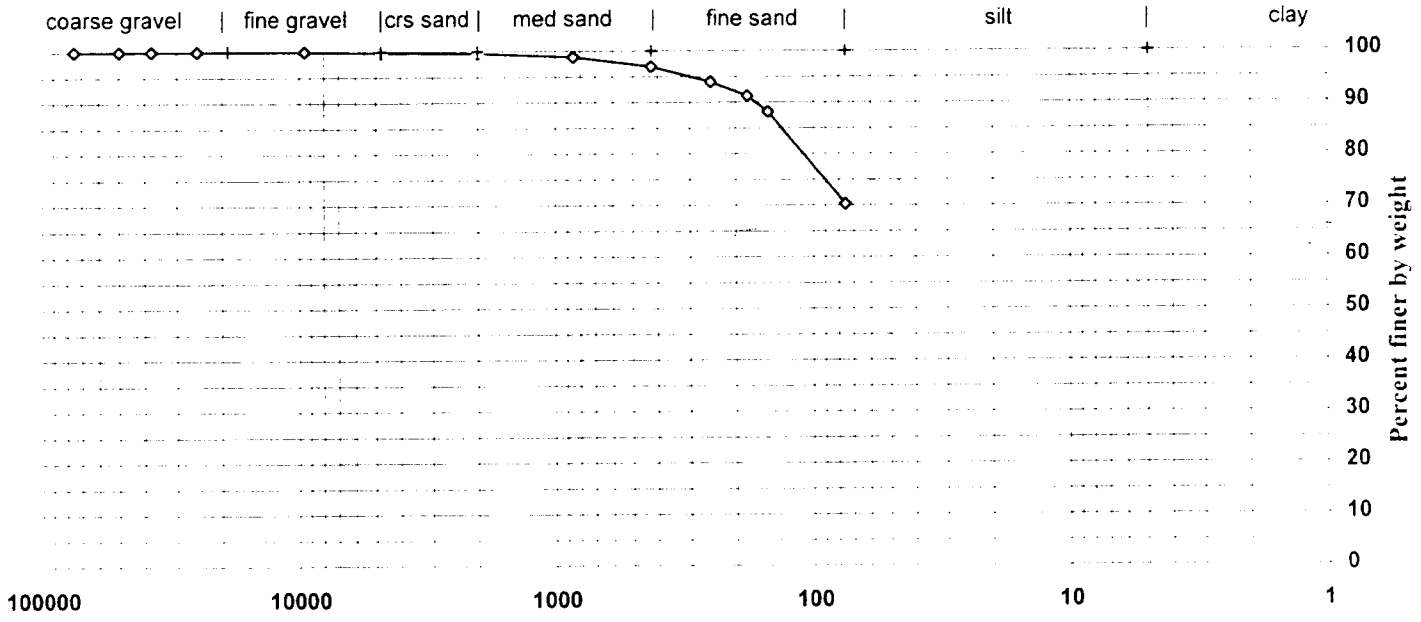
Sample preparation by: D2217

Client:	STL Baltimore	**Project No.:**	20000	**ETR(s) #:**	80372
Client Code:	STLMDB	**Job No.:**	SAICIH	**SDG(s):**	001402
Date Received:	30-Oct-00	**Start Date:**	13-Nov-00	**End Date:**	21-Nov-00

Lab ID: 435464 **Sample ID:** IH-14

Percent Solids: 63.5%
Specific Gravity: 2.65

Maximum Particle Size: 9.5 mm
Shape (> #10): Subangular
Hardness (> #10): Brittle



Sieve size	Particle size, um	Percent finer	Incremental percent
3 inch	75000	100.0	0.0
2 inch	50000	100.0	0.0
1.5 inch	37500	100.0	0.0
1 inch	25000	100.0	0.0
3/4 inch	19000	100.0	0.0
3/8 inch	9500	100.0	0.0
#4	4750	99.8	0.2
#10	2000	99.6	0.2
#20	850	98.9	0.8
#40	425	97.0	1.9
#60	250	94.0	2.9
#80	180	91.3	2.7
#100	150	88.2	3.1
#200	75	70.3	18.0
Hydrometer	0.0	0.0	70.3
|	0.0	0.0	0.0
|	0.0	0.0	0.0
|	0.0	0.0	0.0
|	0.0	0.0	0.0
|	0.0	0.0	0.0
V	0.0	0.0	0.0

Dispersion of soil for hydrometer test by mechanical mixer with metal paddle, operated for at least one minute within a dispersion cup with 125 mls sodium hexametaphosphate

Submitted By: Date: 11/22/00 STL - Burlington 80372ASO.xls::Report

Particle Size of Soils by ASTM D422

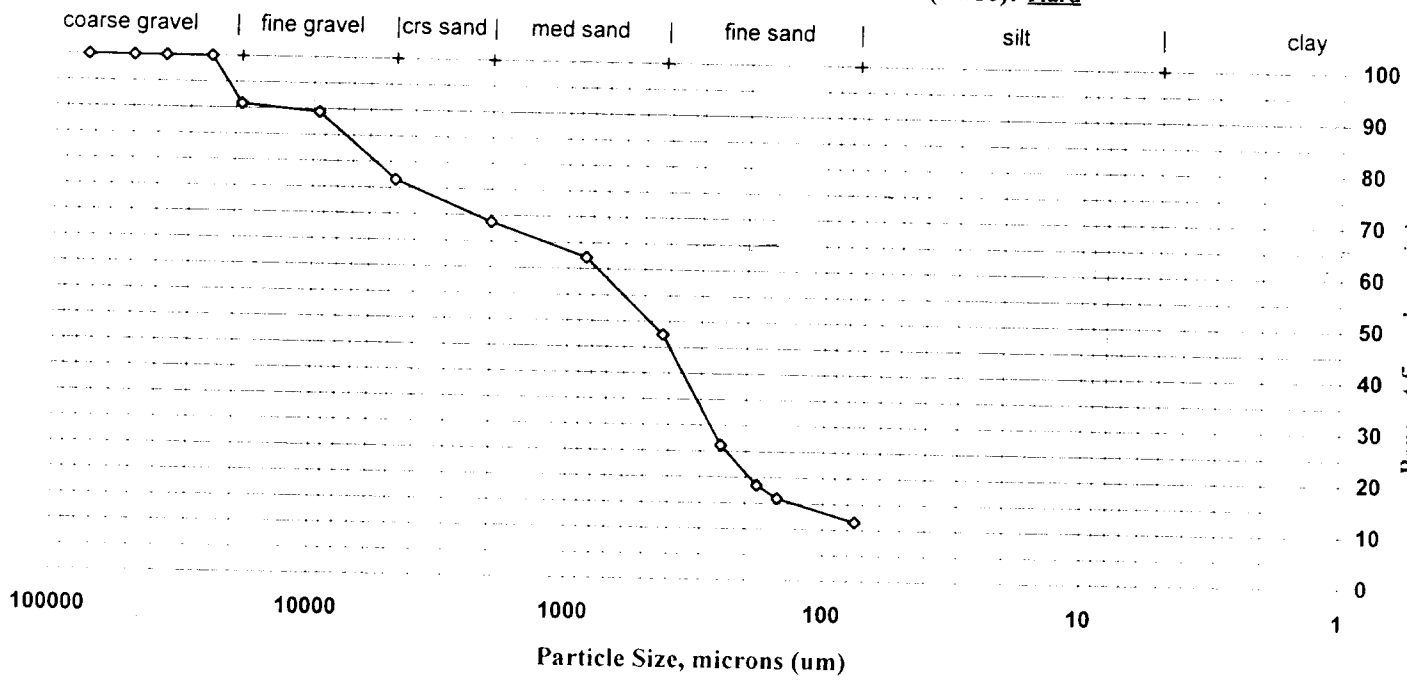
Sample preparation by: **D2217**

Client: STL Baltimore | **Project No.:** 20000 | **ETR(s) #:** 80372
Client Code: STLMDB | **Job No.:** SAICIH | **SDG(s):** 001402
Date Received: 30-Oct-00 | **Start Date:** 13-Nov-00 | **End Date:** 21-Nov-00

Lab ID: 435465 **Sample ID:** IH-15

Percent Solids: 80.2%
Specific Gravity: 2.65

Maximum Particle Size: 25 mm
Shape (> #10): Subrounded
Hardness (> #10): Hard



Sieve size	Particle size, um	Percent finer	Incremental percent
3 inch	75000	100.0	0.0
2 inch	50000	100.0	0.0
1.5 inch	37500	100.0	0.0
1 inch	25000	100.0	0.0
3/4 inch	19000	90.8	9.2
3/8 inch	9500	89.4	1.4
#4	4750	76.6	12.9
#10	2000	68.7	7.8
#20	850	62.2	6.5
#40	425	47.5	14.7
#60	250	26.2	21.3
#80	180	18.5	7.7
#100	150	16.0	2.5
#200	75	11.6	4.4
Hydrometer	0.0	0.0	11.6
|	0.0	0.0	0.0
|	0.0	0.0	0.0
|	0.0	0.0	0.0
|	0.0	0.0	0.0
|	0.0	0.0	0.0
V	0.0	0.0	0.0

Dispersion of soil for hydrometer test by mechanical mixer with metal paddle, operated for at least one minute within a dispersion cup with 125 mls sodium hexametaphosphate

Submitted By: _____ Date: 11/22/00

Appendix B.
TIE Test Results

APPENDIX B-1
Sediment Toxicity Lab Report

SUMMARY REPORT

TOXICITY EVALUATION OF SEDIMENT WITH *Hyalella azteca* SCIENCE APPLICATIONS INTERNATIONAL CORPORATION (S.A.I.C.) PROJECT INDIAN HEAD TIE

Submitted to:
Science Applications International Corporation
221 Third Street
Newport, Rhode Island 02840

SLI Report # 6135.6124

Study Director: Arthur E. Putt

Springborn Laboratories, Inc.
790 Main Street
Wareham, Massachusetts 02571-1075

January 3, 2001

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EXECUTIVE SUMMARY

The following is a summary of testing performed with the freshwater amphipod (*Hyalella azteca*) to evaluate sediment for Science Applications International Corporation (S.A.I.C) project Indian Head TIE. Fifteen test samples were collected and shipped on October 11, 2000 by S.A.I.C personnel. The test samples were identified as: IH-01-CMP, IH-02-CMP, IH-03-CMP, IH-04-CMP, IH-05-CMP, IH-06-CMP, IH-07-CMP, IH-08-CMP, IH-09-CMP, IH-10-CMP, IH-11-CMP, IH-12-CMP, IH-13-CMP, IH-14-CMP, IH-15-CMP. These samples were received at Springborn on October 12, 2000. In addition, Springborn prepared an artificial sediment that was used as the laboratory control sediments. The artificial sediment was prepared by mixing 10% sphagnum peat, 20% kaolin clay and 70% industrial sand (with >50% of the particles between 50 and 200 microns).

The test method used during the conduct of this study followed the "Methods for Measuring the Toxicity and Bioaccumulation of Sediment-associated Contaminants with Freshwater Invertebrates, Second Edition", Test Method 100.1 (U.S. EPA 2000) and ASTM Guideline E 1706-95b "Standard Test Methods for Measuring the Toxicity of Sediment-Associated Contaminants with Fresh Water Invertebrates" (ASTM, 1997). The test method followed during the conduct of this test is attached in Appendix I.

A summary of the Day 0 and Day 10 water quality characteristics of overlying water during the 10-day subchronic test with *Hyalella azteca* is presented in Table 1. Water quality remained acceptable throughout the 10 day exposure period. Dissolved oxygen concentrations were greater than or equal to 3.6 mg/L throughout the study in all exposure vessels and safely above the concentrations of 2.5 mg/L for temperatures between 22 and 24^{o} C. Ammonia concentrations, measured during the exposure in the overlying water, were < 2.66 mg/L in all samples. Water temperature, measured daily in exposure vessels ranged from 23 to 25^{o}C.

A summary of the *Hyalella azteca* survival at termination of the 10-day subchronic test is presented in Table 2. The mean percent Laboratory Control survival was 78%. The mean percent survival in all samples tested (IH-01-CMP to IH-15-CMP) ranged from 0 to 54% and were all statistically different compared to the Laboratory Control organisms.

Conclusions

Results of the samples tested established that the Laboratory Control organism survival was slightly outside the range of acceptance criteria (i.e., 78%). Although the control performance did not meet this acceptance criteria, the results were sufficient to establish adverse effects on amphipod survival associated with all of the samples tested.

SUMMARY OF TEST CONDITIONS
10-Day Sediment Toxicity Tests with *Hyalella azteca*

DATE SAMPLES RECEIVED:	October 12, 2000
TEST DATES:	October 16 to 26, 2000
TEST TYPE:	Whole-sediment toxicity test with renewal of overlying water
TEMPERATURE:	23 to 25°C
LIGHT INTENSITY:	753 to 969 lux
PHOTOPERIOD:	16 hours light, 8 hours dark
TEST CHAMBER SIZE:	300 mL
SEDIMENT VOLUME:	100 mL
OVERLYING WATER VOLUME:	175 mL
RENEWAL OF TEST SOLUTIONS:	2 volume additions/day
AGE OF TEST ORGANISMS:	7 - 14 days old at start of test
NUMBER OF ORGANISMS PER TEST CHAMBER:	10
NUMBER OF REPLICATE TEST CHAMBERS PER TREATMENT:	8
NUMBER ORGANISMS/SAMPLE:	80
FEEDING:	1.5 mL of YCT daily per chamber
AERATION:	None
TEST CONCENTRATION:	100% (no dilutions)
TEST DURATION:	10 days
ENDPOINTS:	Survival
TEST ACCEPTABILITY:	Minimum mean control survival of 80%

Table 1. Water quality summary for *Hyalella azteca* measured during the 10 day exposure.

Sample	Dissolved Oxygen (mg/L)		pH		Ammonia as N (mg/L)	
Identification	Day 0	Day 10	Day 0	Day 10	Day 0	Day 10
Lab Control	7.7 - 8.0	5.0 - 7.2	7.0 - 7.0	6.8 - 6.8	< 0.10	0.26
IH-01-CMP	7.5 - 8.0	6.7 - 7.5	6.7 - 6.7	6.8 - 6.9	< 0.10	<0.10
IH-02-CMP	7.5 - 7.8	6.5 - 7.4	6.8 - 6.8	6.8 - 6.9	< 0.10	<0.10
IH-03-CMP	7.5 - 7.7	6.9 - 7.5	6.6 - 6.7	6.8 - 6.9	< 0.10	<0.10
IH-04-CMP	7.1 - 7.4	6.2 - 6.8	6.9 - 7.0	6.6 - 6.8	< 0.10	0.11
IH-05-CMP	6.6 - 6.9	5.4 - 6.9	6.7 - 6.9	6.9 -7.1	< 0.10	0.10
IH-06-CMP	3.6 - 7.2	5.7 - 6.6	6.4 - 6.8	6.5 - 6.8	1.04	< 0.10
IH-07-CMP	6.9 - 7.4	5.6 - 6.8	6.8 - 6.8	6.7 - 6.9	1.11	< 0.10
IH-08-CMP	7.0 - 7.3	5.8 - 6.2	6.8 - 6.9	6.7 - 6.9	2.66	0.39
IH-09-CMP	7.0 - 7.4	5.7 - 6.4	6.7 - 6.9	6.8 - 6.9	< 0.10	0.10
IH-10-CMP	5.9 - 7.2	5.8 - 6.6	6.7 - 6.8	6.7 - 6.8	< 0.10	< 0.10
IH-11-CMP	6.5 - 7.2	5.4 - 6.4	6.7 - 6.9	6.8 - 6.9	0.15	0.30
IH-12-CMP	6.8 - 7.2	5.7 - 6.2	6.7 - 6.8	6.7 - 6.8	< 0.10	0.15
IH-13-CMP	6.8 - 7.5	5.1 - 6.1	6.8 - 6.9	6.8 - 6.9	< 0.10	0.17
IH-14-CMP	7.4 - 7.7	6.0 - 6.9	6.9 - 6.9	6.8 - 6.9	< 0.10	< 0.10
IH-15-CMP	7.8 - 8.0	5.9 - 6.9	6.8 - 6.9	6.8 - 6.9	< 0.10	< 0.10

Sample	Alkalinity (mg/L as $CaCO_3$)		Hardness (mg/L as $CaCO_3$)		Conductivity (µmhos/cm)	
Identification	Day 0	Day 10	Day 0	Day 10	Day 0	Day 10
Lab Control	30	30	48	48	180	170
IH-01-CMP	28	26	44	40	150	130
IH-02-CMP	28	30	44	40	160	160
IH-03-CMP	24	24	36	40	150	140
IH-04-CMP	34	34	56	44	190	180
IH-05-CMP	30	26	40	44	160	160
IH-06-CMP	32	24	40	40	170	150
IH-07-CMP	30	22	40	44	170	160
IH-08-CMP	42	24	44	40	190	200
IH-09-CMP	38	28	48	40	170	180
IH-10-CMP	40	24	36	40	190	190
IH-11-CMP	38	28	44	40	170	160
IH-12-CMP	30	28	40	44	160	150
IH-13-CMP	38	30	40	44	170	170
IH-14-CMP	32	28	36	44	160	170
IH-15-CMP	28	28	40	44	150	160

Table 2. Summary of the survival and growth of *Hyalella azteca* after a 10 day exposure.

Sample Identification	Mean Percent Survival (Standard Deviation)
Lab Control	79(15)
IH-01-CMP	28(25) *
IH-02-CMP	53(16) *
IH-03-CMP	33(19) *
IH-04-CMP	29(24) *
IH-05-CMP	41(21) *
IH-06-CMP	54(16) *
IH-07-CMP	20(19) *
IH-08-CMP	33(21) *
IH-09-CMP	33(31) *
IH-10-CMP	1(4) *
IH-11-CMP	8(18) *
IH-12-CMP	0(0) *
IH-13-CMP	24(19) *
IH-14-CMP	18(22) *
IH-15-CMP	0(0) *

* Statistically different ($p \leq 0.050$) compared to the Lab Control data.

REFERENCES

ASTM. 1997. Guideline E 1706-95b *Standard Test Methods for Measuring the Toxicity of Sediment-Associated Contaminants with Fresh Water Invertebrates* Volume 11.05. ASTM 100 Barr Harbor Drive, West Conshohocken, PA.

U.S. EPA. 2000. Methods for Measuring the Toxicity and Bioaccumulation of Sediment-associated Contaminants with Freshwater Invertebrates. 2nd Edition. U.S. Environmental Protection Agency. Office of Research and Development. EPA/600/R-99/064.

APPENDIX I

10-Day Toxicity Test with Freshwater Amphipod (*Hyalella azteca*) to Meet U.S. EPA Guidelines.

1.0 INTRODUCTION

The objective of this study is to determine the toxicity of a contaminated sediment sample(s) to amphipod (*Hyalella azteca*) during a 10-day exposure. Amphipods are exposed to the sediment sample to assess survival on test day 10 (test termination). The methods (Springborn Laboratories test method #: SED-Ha-121) described in this study plan meet the standard procedures described in the "Methods for Measuring the Toxicity and Bioaccumulation of Sediment-associated Contaminants with Freshwater Invertebrates, 2nd Edition", test method 100.1 (U.S. EPA 2000) and ASTM Guideline E 1706-95b "Standard Test Methods for Measuring the Toxicity of Sediment-Associated Contaminants with Fresh Water Invertebrates" (ASTM, 1997).

2.0 MATERIALS AND METHODS

2.1 Test

2.1.1 Species

The freshwater invertebrate, *Hyalella azteca,* is the species used in this test. Test organisms will be 7 to 14 days old at initiation of the test. Amphipods used in the exposure will be the young amphipods produced by adult amphipods removed from culture tanks 7 to 14 days prior to test initiation. The adult amphipods are placed in 9.5 liter aquaria with approximately 8L of water. Young produced by these isolated adults will then be removed and pipetted into holding containers until test initiation. Amphipods will not be used if >10% mortality is observed during the 48 hours prior to test initiation.

2.1.2 Source

Hyalella azteca cultures will be maintained at Springborn Laboratories, Inc. Amphipods will be cultured in 20 liter glass aquaria (containing approximately 10-L of culture water) under flow-through conditions. Water used to culture the amphipods is similar to the overlying water used during the 10-day test. Culture water will be maintained at 23 ± 1°C.

2.1.3 Feeding

While being maintained in the culture prior to the test, adult and juvenile amphipods will be fed every other day. They will be fed a combination of Yeast, Cereal leaves and flaked fish food suspension (YCT) and a unicellular green algae *Psueokirchneriella subcapitata*. During testing, 1.5 mL of YCT Suspension will be added daily to each test vessel. If food collects on the sediment surface during testing, feeding will be suspended for one or more days.

2.1.4 Handling

Wide-bore pipets will be used to transfer the amphipods, taking care to minimize possible stress due to handling. Amphipods that are damaged or dropped during transfer will not be used.

2.2 Physical System

2.2.1 Sediment

Sediment samples should be shipped overnight to Springborn Laboratories after collection. Upon receipt at Springborn, sample containers will be inspected for leakage or damage and the sample identity recorded. If storage is required, the samples will be refrigerated at approximately 4 °C. In addition, a sediment sample will be collected from an uncontaminated location near the site of interest to be used as a reference sediment. A laboratory control sediment, prepared or collected by Springborn Laboratories, will be included in the test to evaluate performance of the test organisms and exposure system. The test will be initiated within 14 days of sediment collection.

2.2.2 Test Vessels

The test vessels used in the static-renewal toxicity test will be 300 mL glass beakers which are chemically clean. Each test vessels has a 2-cm hole cut on the top portion of the vessel and is covered with 40-mesh Nitex® screen for drainage. Each vessel will contain 100 mL (approximately 2 cm layer) of sediment and 175 mL of overlying water. Test vessels will be cleaned by an appropriate method to remove residue of test substance previously used (i.e., acid to remove metals and bases; detergents and organic solvents to remove organic compounds) and rinsed several times using diluent water.

2.2.3 Overlying Water

Water from a 100 meter bedrock well is pumped to a concrete reservoir where it is supplemented on demand with untreated, unchlorinated, Town of Wareham well water. The water is characterized as being "soft" with a normal pH range of 6.9 - 7.7, a total hardness of 30 - 60 mg/L and a specific conductance of 110 - 160 µmhos/cm. The pH, total hardness, alkalinity, and specific conductance of this water will be monitored weekly at a central location in the laboratory to assure that these parameters are within the normal, acceptable ranges. Total hardness and alkalinity will be determined according to *Standard Methods for the Water and Wastewater*, (APHA, 1992).

The quality of the water is judged by periodic analyses of representative samples conducted to ensure the absence of potential toxicants, including pesticides, PCBs and selected toxic metals, at concentrations which may be harmful to the amphipods, as well as the ability of amphipod cultures to survive and reproduce in the water free of stress.

2.3 Test Procedures:

2.3.1 Test Concentration

Eight replicates will be maintained for each sediment sample consisting of 100% whole sediment sample (no dilutions). A reference control (if collected), conducted with eight replicates, will be used to evaluate the survival and growth potential of the test organism in a non-contaminated sediment. In addition, a laboratory control sediment, prepared or collected by Springborn Laboratories, will also be used to evaluate the survival and growth potential of the test organisms. The laboratory control sediment will also be conducted with eight replicates. Ten amphipods (7 to 14 days old) per replicate (80 organisms per sediment sample or control) will be used to initiate the test.

2.3.2 Test Initiation

The day before test initiation (day -1) test sediment, reference control and laboratory control sediments will be added to the replicate test vessels and the overlying water added. Prior to addition to the test vessels, each sediment sample will be wet pressed through a 2.0 mm stainless steel sieve to remove any potential predators. The water will be added gently to prevent resuspension of the sediment layer in the water column. This allows the sediment and water to equilibrate prior to addition of the test organisms

The juvenile amphipods (7 to 14 days old), produced by isolated adults, will be removed from the holding vessels (see section 2.1.1). Ten juvenile amphipods will be randomly selected and pipeted into a replicate test or control vessel. This procedure will be repeated until all vessels contain ten amphipods (eighty per test sample and control). Test vessels will be inspected within 1 hour after the juvenile amphipods are introduced to ensure organisms are not trapped in the surface tension or not burrowed into the sediment. During this one hour period, organisms observed to be trapped in the surface tension or not burrowed will be replaced with new juvenile amphipods.

2.3.3 Renewal of Overlying Water

During the 10-day study, the overlying water will be renewed by adding two volume additions (i.e., 350 mL) per day using an intermittent delivery system in combination with a calibrated water-distribution system (Zumwalt et al., 1994). The intermittent delivery system will be calibrated to provide 1 liter of water per cycle to the water-distribution system, which subsequently provides 50 mL of water per cycle to each replicate test chamber. The water delivery system cycles 7 times per day, providing 2 volume additions every 24 hours. Delivery of two volume replacements per day is sufficient to provide consistent and acceptable water quality characteristics throughout the duration of the 10 day exposure.

2.3.4 Photoperiod

The test vessels will be located in an area illuminated to a light intensity of 500 to 1000 lux using a combination of fluorescent bulbs. A 16-hour light, 8-hour dark photoperiod will be maintained with an automatic timer. Sudden transitions from light to dark and vice versa

will be avoided.

2.3.5 Measurement of Water Quality Variables

Total hardness, alkalinity, specific conductance, pH and ammonia will be determined at test initiation and test termination in the overlying water from a composite sample from all eight replicate vessels. The composite sample will be taken from 1 to 2 cm from the sediment surface using a pipet. Dissolved oxygen and temperature will be measured in all replicate vessels at test initiation and test termination. Dissolved oxygen and temperature will be monitored daily in one alternating replicate during the course of the study (test days 1-9). Temperature will be monitored continuously in the waterbath using a minimum-maximum thermometer. Readings of temperature extremes will be recorded daily.

2.3.6 Dissolved Oxygen

Total dissolved oxygen will not be allowed to drop below 2.5 mg/L at 23°C. Aeration (with oil-free air) will be initiated to raise and maintain the dissolved oxygen concentration at or above 2.5 mg/L.

2.3.7 Temperature

Temperature of the overlying water will be maintained at 23 ± 1°C by conducting the study in a temperature controlled waterbath maintained at the appropriate test temperature.

2.3.8 Biological Data

Survival of the amphipods will be determined in each test vessel at test termination (test day 10) by sieving the sediment to remove all surviving amphipods. In addition, daily observations of organism behavior (e.g., sublethal effects) and characteristics of sediment and overlying water will also be observed and recorded daily. Dead organisms are removed from the exposure vessels daily.

2.3.9 Test Acceptability

At termination of the study, mean survival of the amphipods in the laboratory control must be $\geq$ 80%.

3.0 STATISTICAL ANALYSES

The mean survival of organisms exposed in each test sediment and reference control sample will be tested for normality and homogeneity of variance using Shapiro-Wilks Test and Ba F-Test. If the data set passes these two tests, then a parametric method (e.g., ANOVA 2-Sample T-Test or Dunnett's Test) will be used to evaluate the results of the mean survival of each test sample for significant adverse effects. If the data set fails the test for normality and homogeneity of variance, then a non-parametric method (e.g., Steel's Many-One Rank Test) will be used to determine significant adverse effects. If necessary, mean survival values will be transformed (e.g., arcsine square).

4.0 REPORTING

The raw data and the final summary report will be reviewed by the Study Director. The test results will be presented in an outline format on a per sample basis.

5.0 REFERENCES

APHA, AWWA, WPCF. 1992. *Standard Methods for the Examination of Water and Wastewater*. 18th Edition, Washington, D.C.

ASTM. 1997. Guideline E 1706-95b *Standard Test Methods for Measuring the Toxicity of Sediment-Associated Contaminants with Fresh Water Invertebrates* Volume 11.05. ASTM 100 Barr Harbor Drive, West Conshohocken, PA.

U.S. EPA. 2000. Methods for Measuring the Toxicity and Bioaccumulation of Sediment-associated Contaminants with Freshwater Invertebrates. 2nd Edition. U.S. Environmental Protection Agency. Office of Research and Development. EPA/600/R-99/064.

Zumwalt, D.C., F.J. Dwyer, I.E. Greer and C.G. Ingersoll. 1994. A water-renewal system that accurately delivers small volumes of water to exposure chambers. Environmental Toxicology and Chemistry. pgs. 1311-1314.

SIGNATURES AND APPROVAL

SUBMITTED BY:

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PREPARED BY:

January 03, 2001

Arthur E. Putt Date
Study Director

1·3·01

Ronald C. Biever Date
Manager,
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Appendix B-2. Percent survival of *Hyalella azteca* and *Pimephales promelas* in Indian Head TIE treatments by dilution.

Hyalella azteca

	TIE Treatment Result (% Survival)[1]								
Station-dilution	Untreated	Filtered	C_{18}	$Na_2S_2O_3$	EDTA	Zeolite		Low pH[2]	High pH[2]
Spike - 10	**0**	--	**0**	85					
Spike - 25	**0**	--	**0**	89					
Spike - 50	**0**	--	**0**	100					
Spike - 100	**0**	--	**0**	100					
IH1 - 10	93								
IH1 - 25	100								
IH1 - 50	100								
IH1 - 100	100								
IH2 - 10	**0**	**0**	**0**	**36**	**38**	100		93	**13**
IH2 - 25	**0**	**0**	**0**	**0**	**0**	67		**35**	**0**
IH2 - 50	**0**	**0**	**0**	**0**	**0**	**0**		**0**	**0**
IH2 - 100	**0**	**0**	**0**	**0**	**0**	**0**		**0**	**0**
IH5 - 10	93								
IH5 - 25	100								
IH5 - 50	93								
IH5 - 100	87								
IH6 - 10	100								
IH6 - 25	92								
IH6 - 50	50	**53**	87						
IH6 - 100	**27**	**18**	33	**0**	89				
IH8 - 10	100								
IH8 - 25	73	92							
IH8 - 50	**27**	73	**18**	**13**	58	100		89	83
IH8 - 100	40	48	**47**	13	50	100		83	**7**
IH10 - 10	93								
IH10 - 25	88								
IH10 - 50	100								
IH10 - 100	93								
IH11 - 10	100								
IH11 - 25	71	100							
IH11 - 50	**65**	**72**	**67**	77	92				
IH11 - 100	**27**	89	**47**	74	92				
IH12 - 10	100								
IH12 - 25	100								
IH12 - 50	93								
IH12 - 100	93								
IH13 - 10	100								
IH13 - 25	100								
IH13 - 50	92								
IH13 - 100	**66**	100							
IH15 - 10	**0**	**0**	**13**	**0**	100				
IH15 - 25	**0**	**0**	**0**	**0**	92				
IH15 - 50	**0**	**0**	**0**	**0**	78				
IH15 - 100	**0**	**0**	**0**	**0**	100				
PC-100	100	100	100	100	100	100		100	60

Bold values are statistically different from the control survival @ alpha = 0.05; "--" = not tested

1- Data for treatment reported where prior treatment was statistically different from the control survival @ alpha = 0.05 and <80% of control survival

2- pH treatment data reported where residual toxicity in EDTA treatment was observed.

Appendix B-2. continued.

Pimephales promelas

	TIE Treatment Result (% Survival)[1]				
Station-dilution	Untreated	Filtered	C_{18}	$Na_2S_2O_3$	EDTA
Spike - 10	**0**	--	88		
Spike - 25	**0**	--	**20**	100	
Spike - 50	**0**	--	**0**	93	
Spike - 100	**0**	--	**0**	93	
IH01 - 10	100				
IH01 - 25	100				
IH01 - 50	100				
IH01 - 100	100				
IH02 - 10	**0**	--	**0**	93	
IH02 - 25	**0**	--	**0**	**0**	**0**
IH02 - 50	**0**	--	**0**	**0**	**0**
IH02 - 100	**0**	--	**0**	**0**	**0**
IH05 - 10	100				
IH05 - 25	100				
IH05 - 50	100				
IH05 - 100	**0**	**0**	**0**	87	
IH06 - 10	93.3				
IH06 - 25	100				
IH06 - 50	**30**	85			
IH06 - 100	**0**	**0**	**0**	**0**	**0**
IH08 - 10	100				
IH08 - 25	100				
IH08 - 50	**0**	**0**	**0**	**40**	**0**
IH08 - 100	**0**	**0**	**0**	**0**	**0**
IH10 - 10	93				
IH10 - 25	100				
IH10 - 50	100				
IH10 - 100	100				
IH11 - 10	100				
IH11 - 25	100				
IH11 - 50	100				
IH11 - 100	**0**	**0**	**0**	**0**	**0**
IH12 - 10	100				
IH12 - 25	100				
IH12 - 50	100				
IH12 - 100	100				
IH13 - 10	100				
IH13 - 25	100				
IH13 - 50	100				
IH13 - 100	93				
IH15 - 10	**0**	**0**	**0**	**0**	100
IH15 - 25	**0**	**0**	**0**	**0**	100
IH15 - 50	**0**	**0**	**0**	**0**	100
IH15 - 100	**0**	**0**	**0**	**0**	100
PC-100	100	100	100	93	100

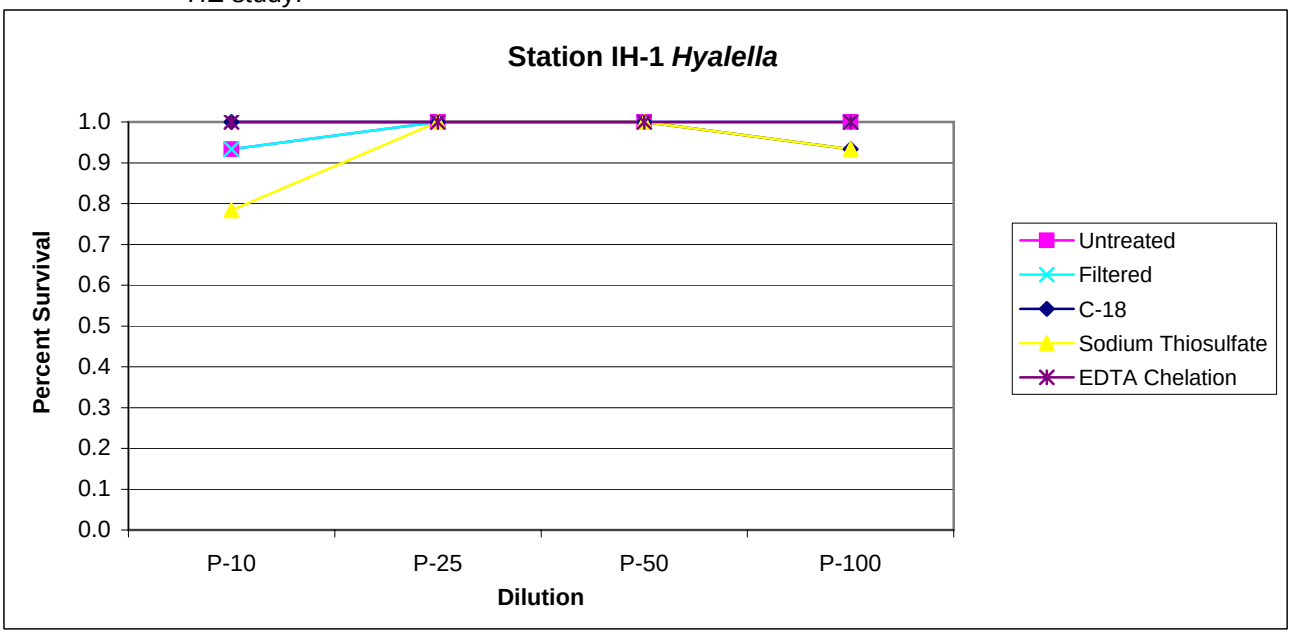
Bold values are statistically different from the control survival @ alpha = 0.05; "--" = not tested

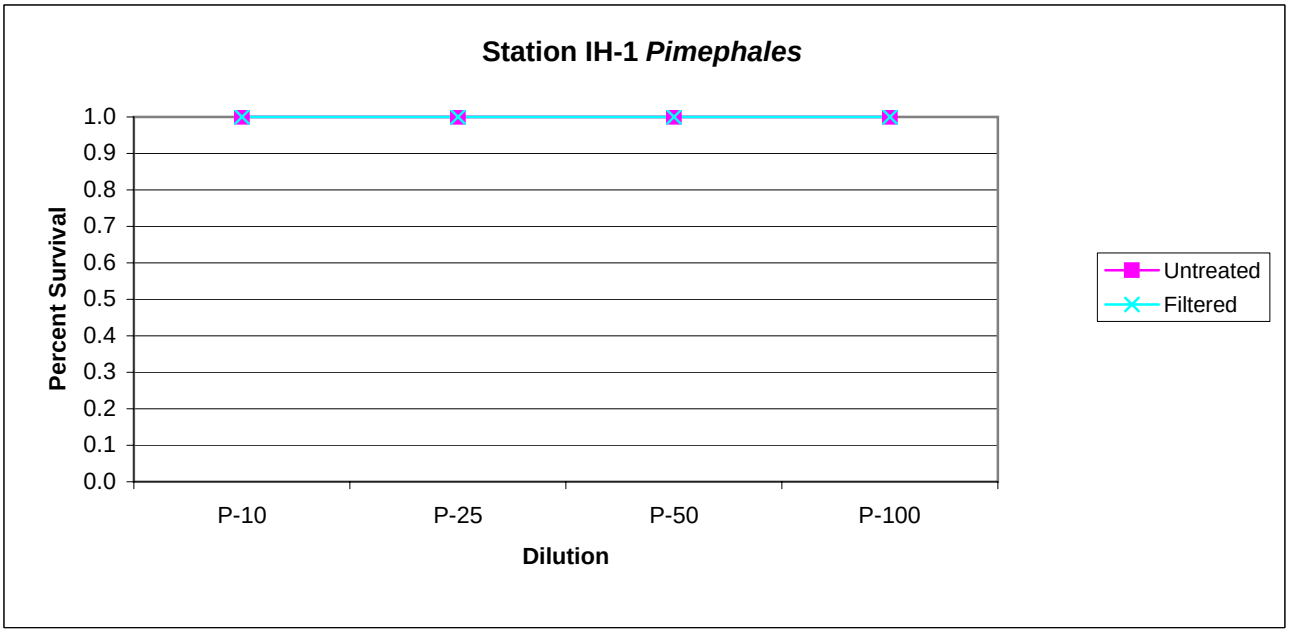
1- Data for treatment reported where prior treatment was statistically different from the control survival @ alpha = 0.05 and <80% of control survival

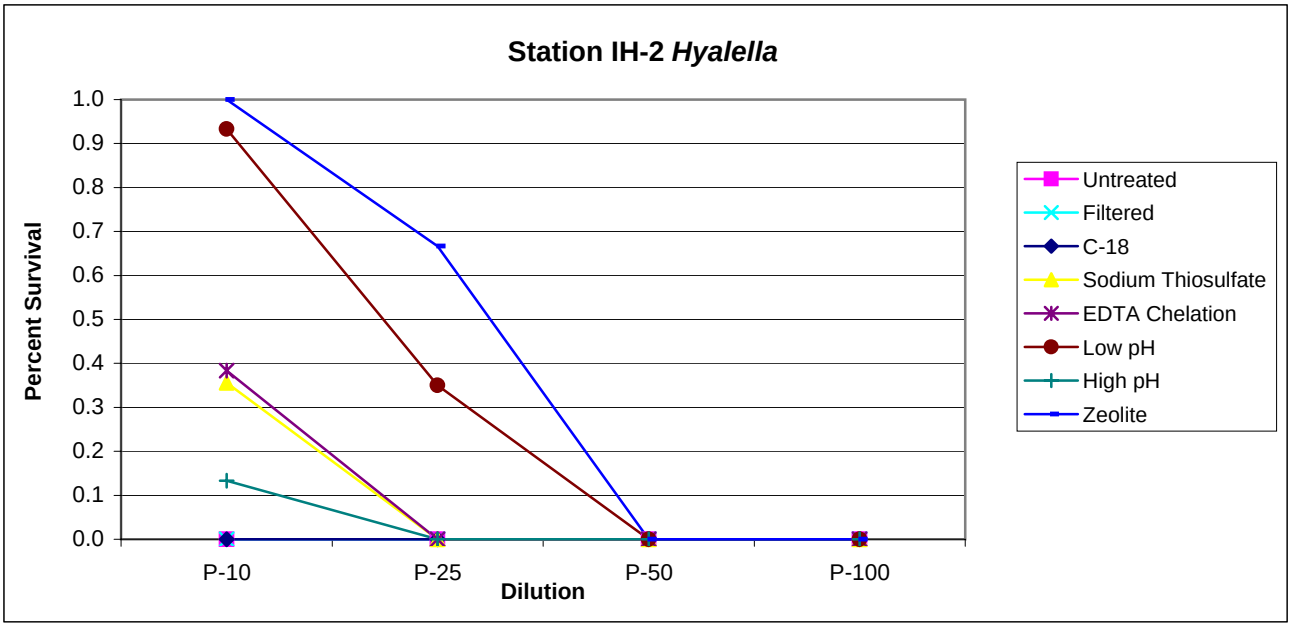
2- pH treatment data reported where residual toxicity in EDTA treatment was observed.

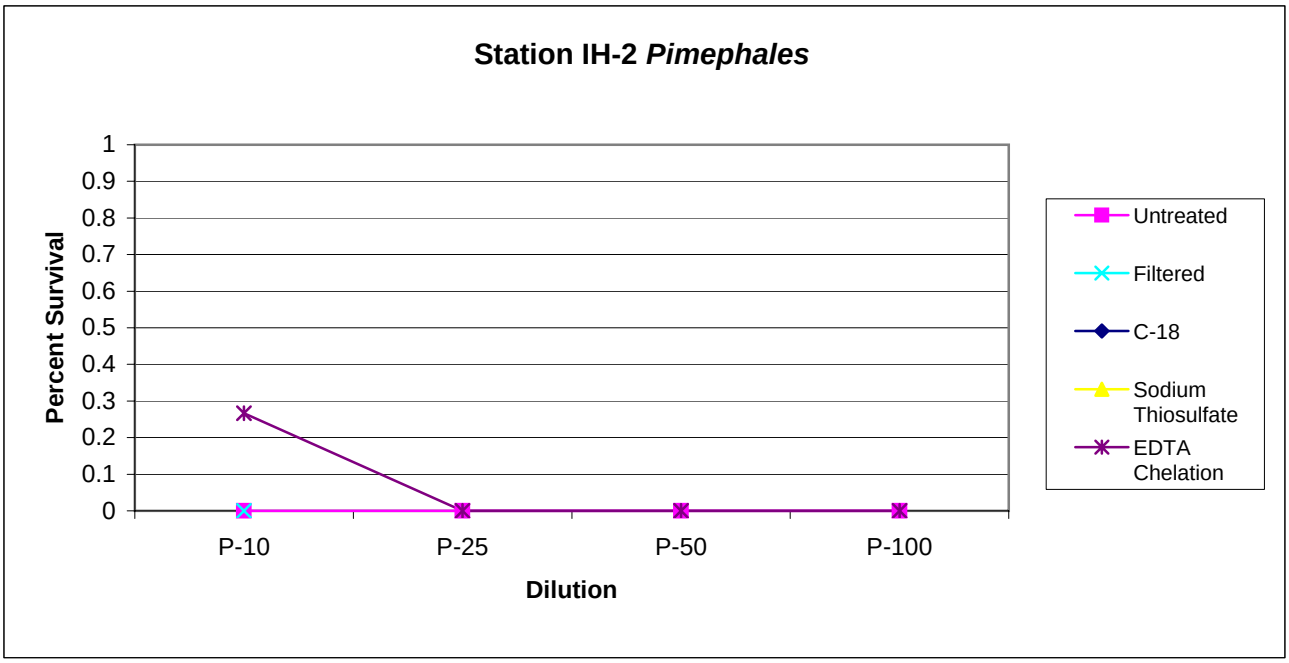
APPENDIX B-3
Plots of percent survival vs. sample dilution by station and species

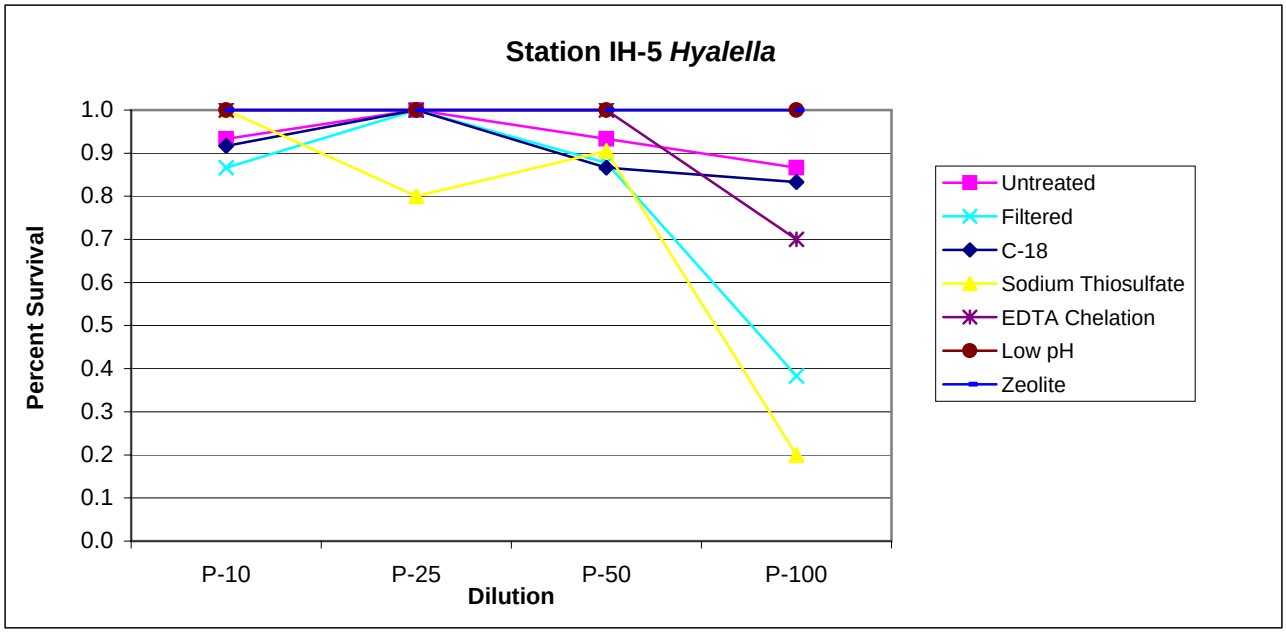
Appendix B-3. Plots of percent survival vs. sample dilution by station and species for the Indian Head TIE study.

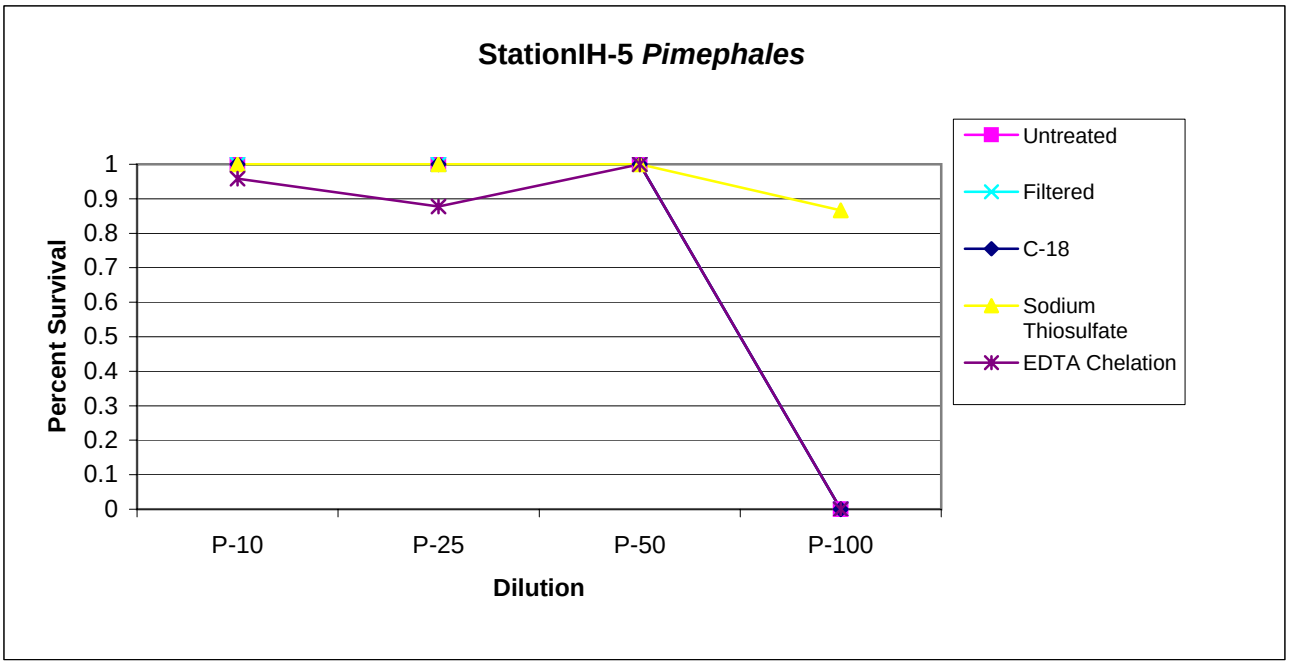


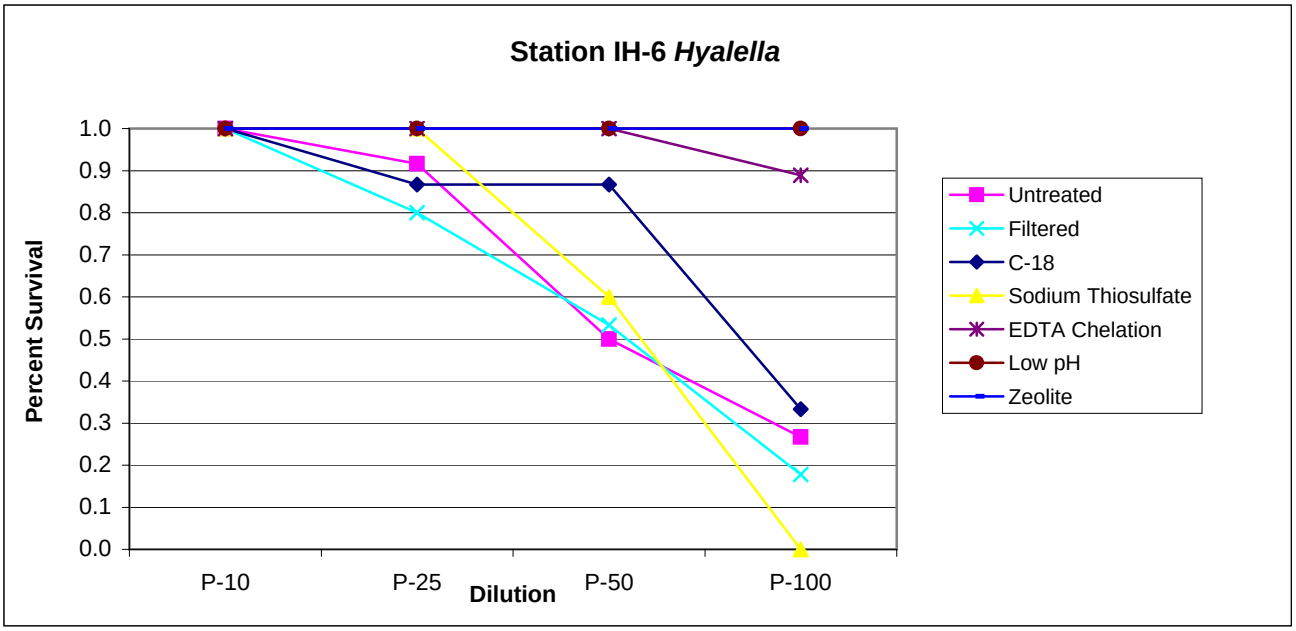



Station IH-2 *Hyalella*
Percent Survival
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
P-10
P-25
P-50
P-100
Dilution
Untreated
Filtered
C-18
Sodium Thiosulfate
EDTA Chelation
Low pH
High pH
Zeolite


Station IH-2 *Pimephales*
Percent Survival
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
P-10
P-25
P-50
P-100
Dilution
Untreated
Filtered
C-18
Sodium Thiosulfate
EDTA Chelation


Station IH-5 *Hyalella*
Percent Survival
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
P-10
P-25
P-50
P-100
Dilution
Untreated
Filtered
C-18
Sodium Thiosulfate
EDTA Chelation
Low pH
Zeolite


StationIH-5 *Pimephales*
Percent Survival
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
P-10
P-25
P-50
P-100
Dilution
Untreated
Filtered
C-18
Sodium Thiosulfate
EDTA Chelation


Station IH-6 *Hyalella*
Percent Survival
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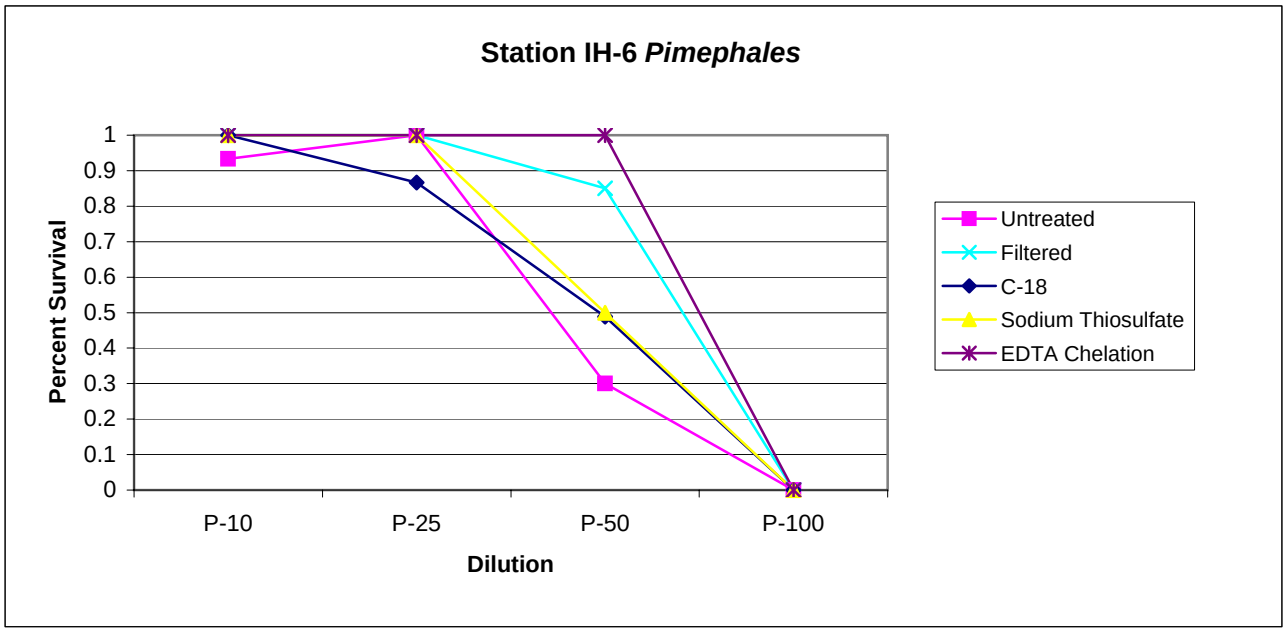
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
P-10
P-25
P-50
P-100
Dilution
Untreated
Filtered
C-18
Sodium Thiosulfate
EDTA Chelation
Low pH
Zeolite


Station IH-6 *Pimephales*
Percent Survival
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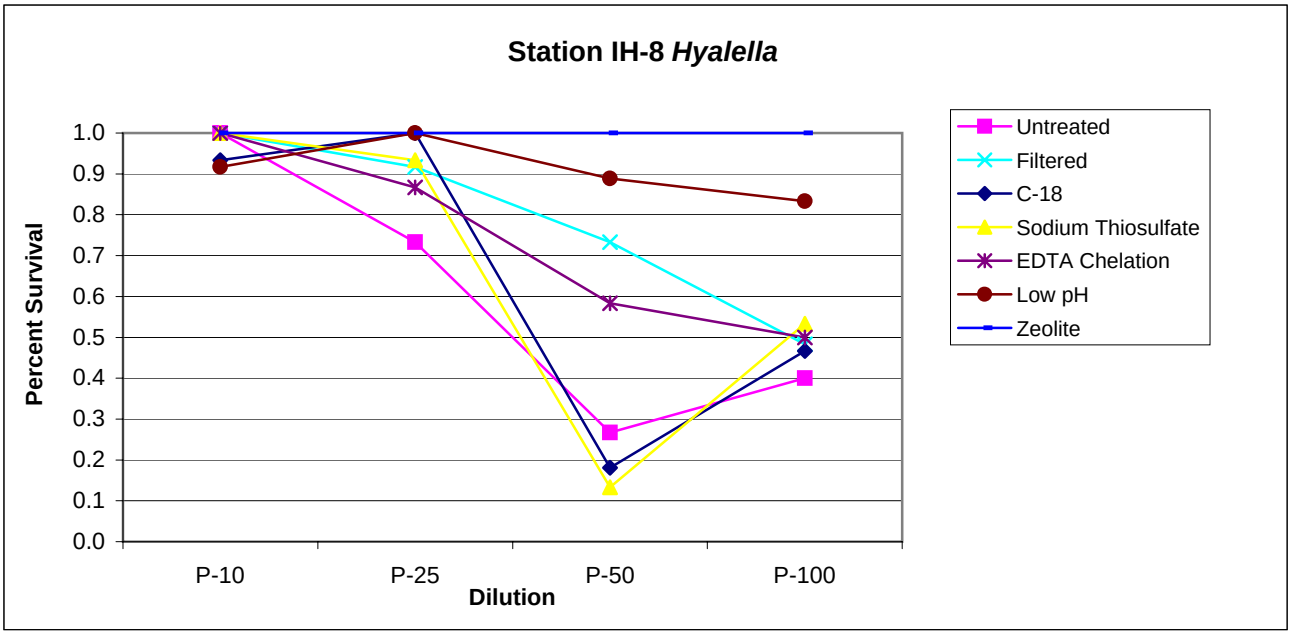
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
P-10
P-25
P-50
P-100
Dilution
Untreated
Filtered
C-18
Sodium Thiosulfate
EDTA Chelation


Station IH-8 *Hyalella*
Percent Survival
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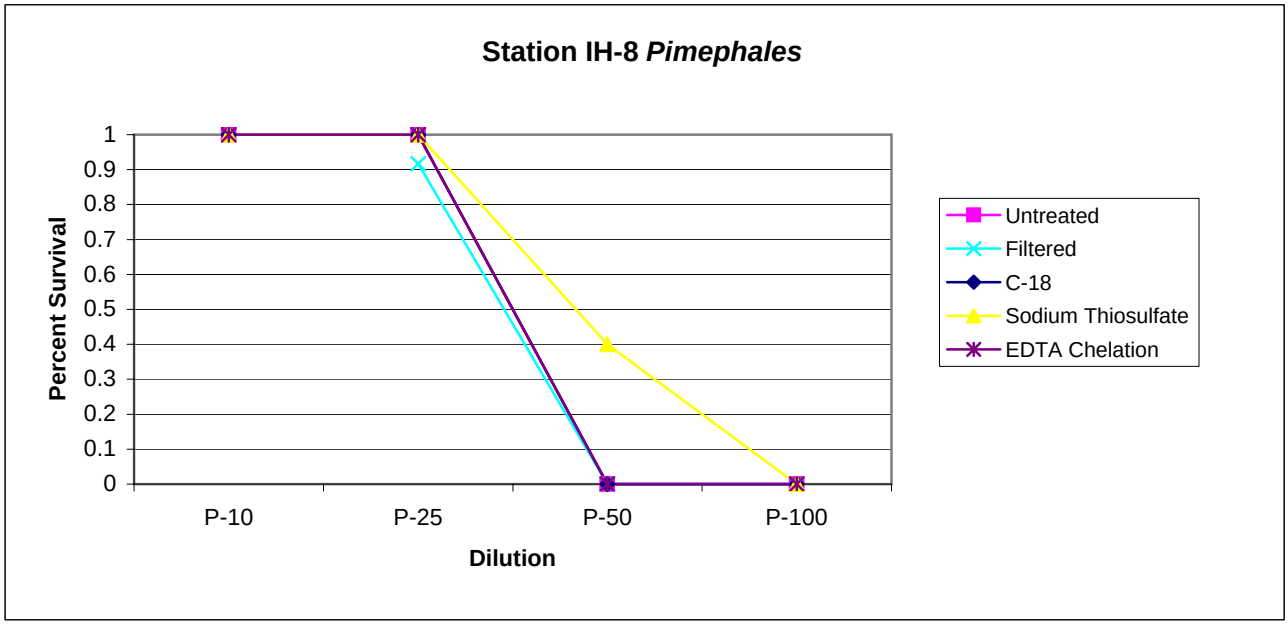
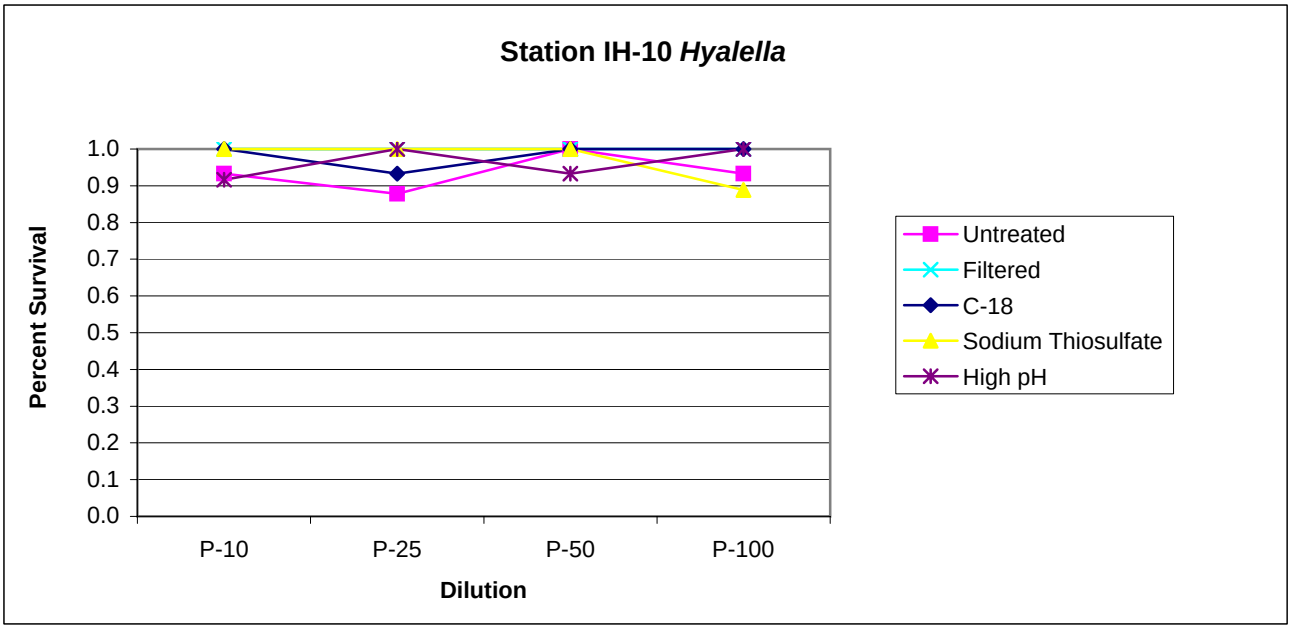
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
P-10
P-25
P-50
P-100
Dilution
Untreated
Filtered
C-18
Sodium Thiosulfate
EDTA Chelation
Low pH
Zeolite


Station IH-8 *Pimephales*
Percent Survival
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
P-10
P-25
P-50
P-100
Dilution
Untreated
Filtered
C-18
Sodium Thiosulfate
EDTA Chelation


Station IH-10 *Hyalella*
Percent Survival
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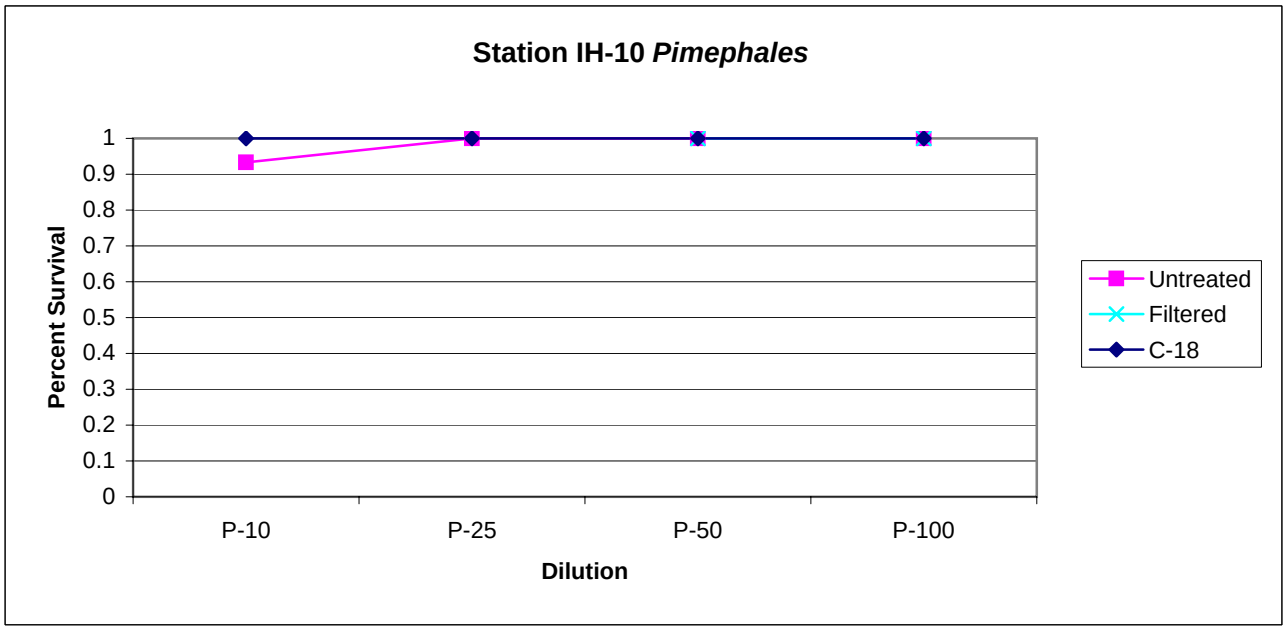
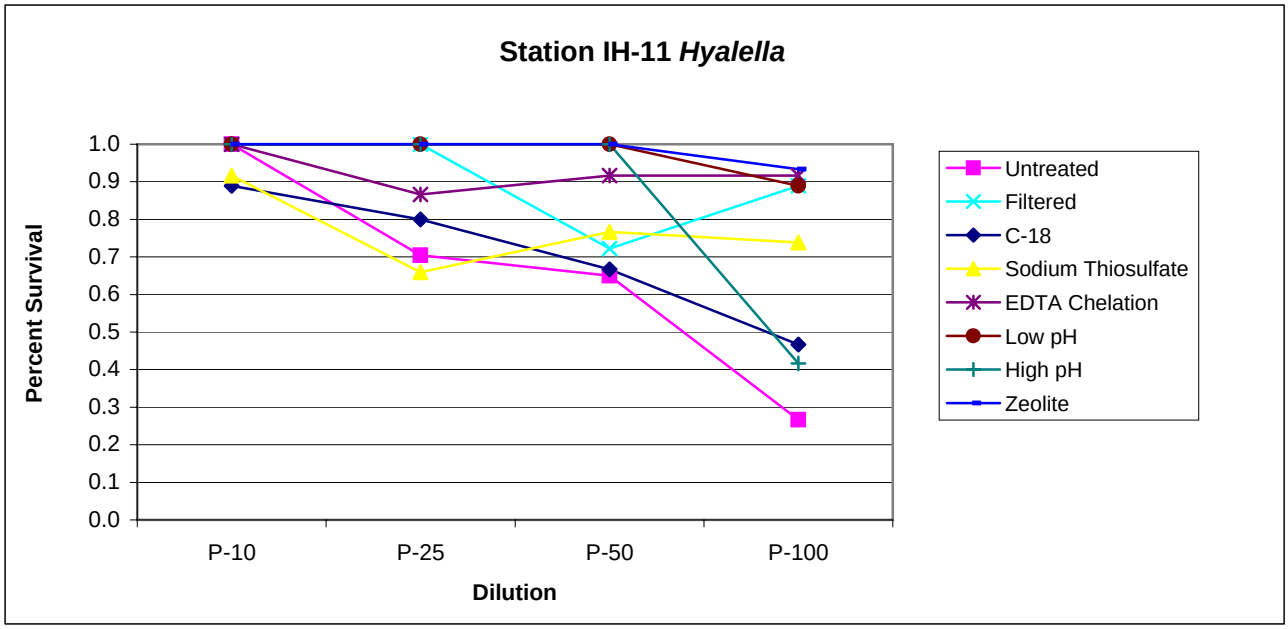
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
P-10
P-25
P-50
P-100
Dilution
Untreated
Filtered
C-18
Sodium Thiosulfate
High pH


Station IH-10 *Pimephales*
Percent Survival
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
P-10
P-25
P-50
P-100
Dilution
Untreated
Filtered
C-18


Station IH-11 *Hyalella*
Percent Survival
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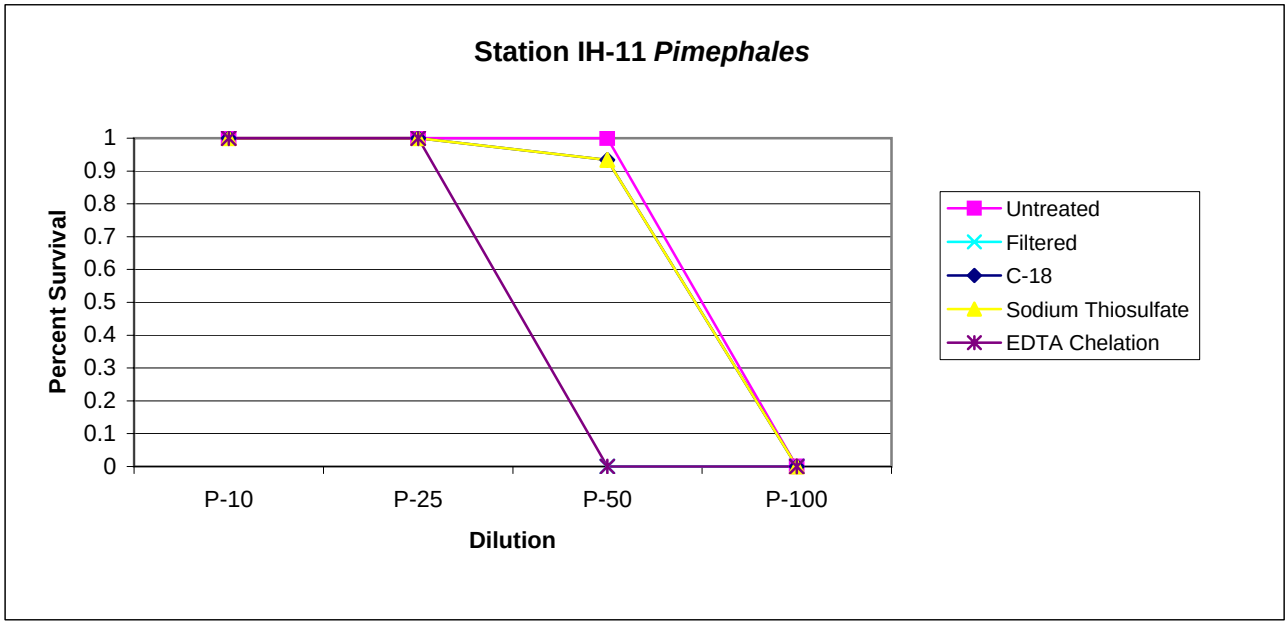
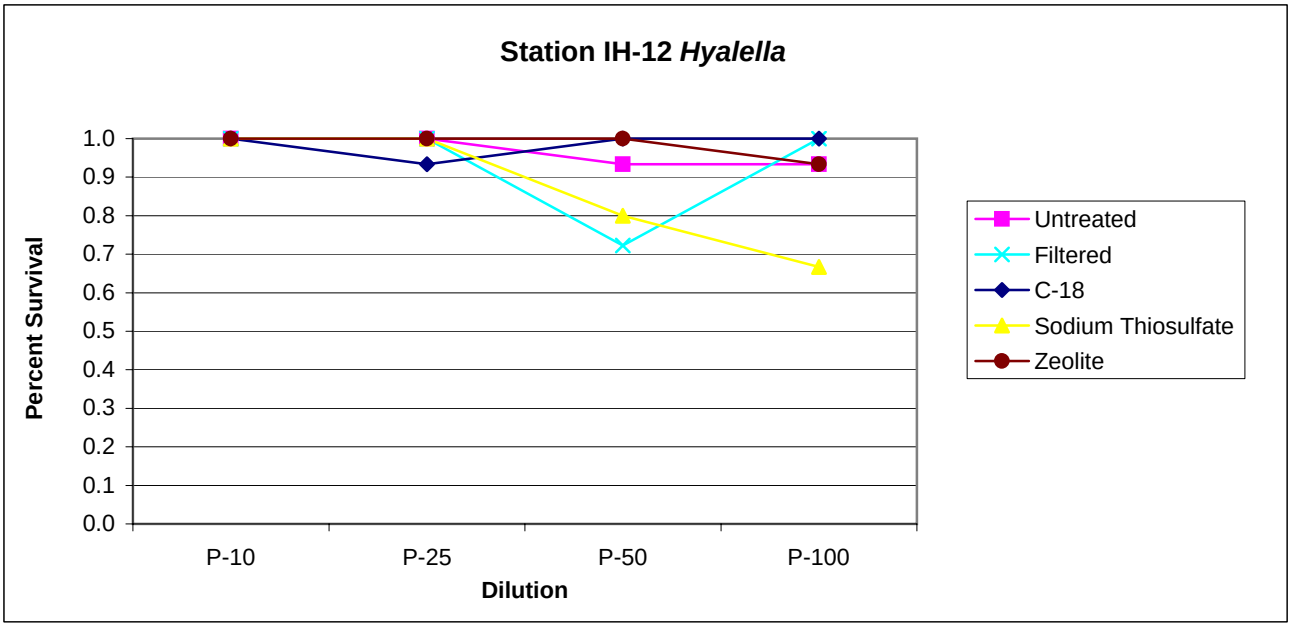
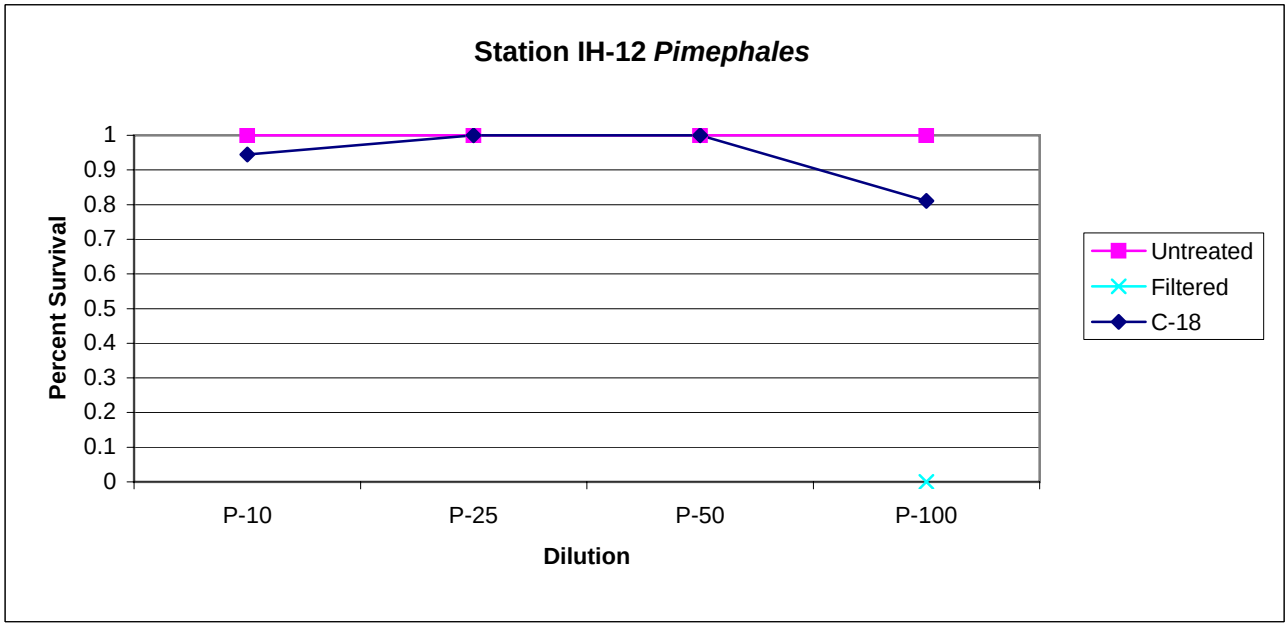
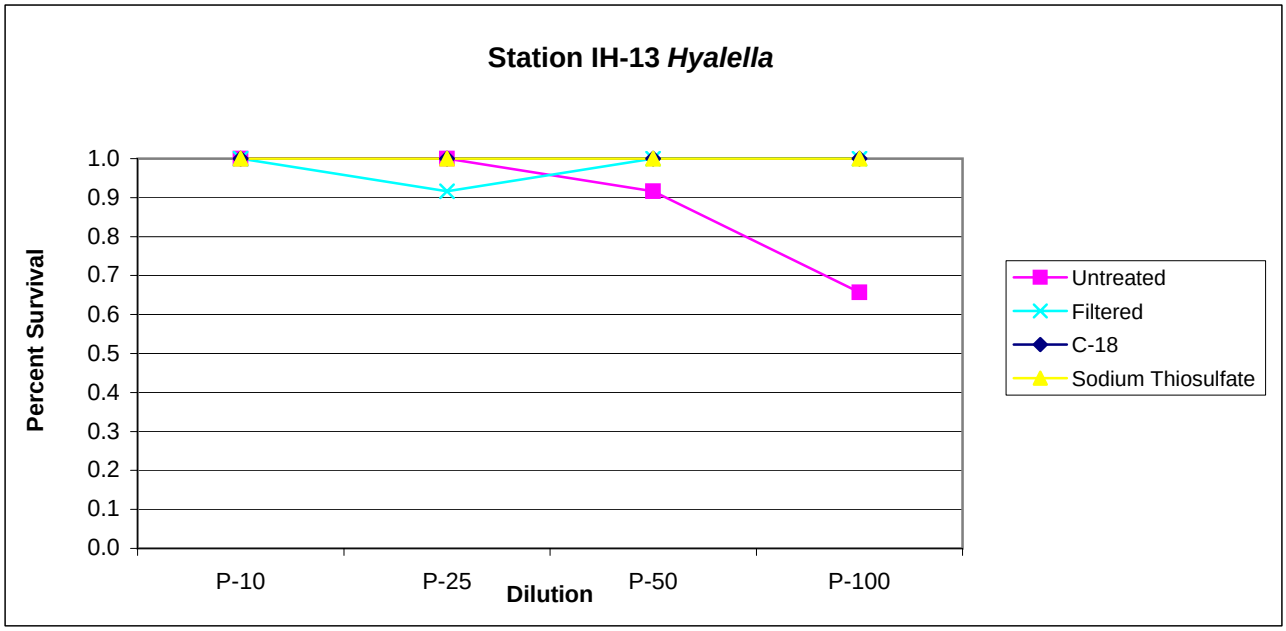
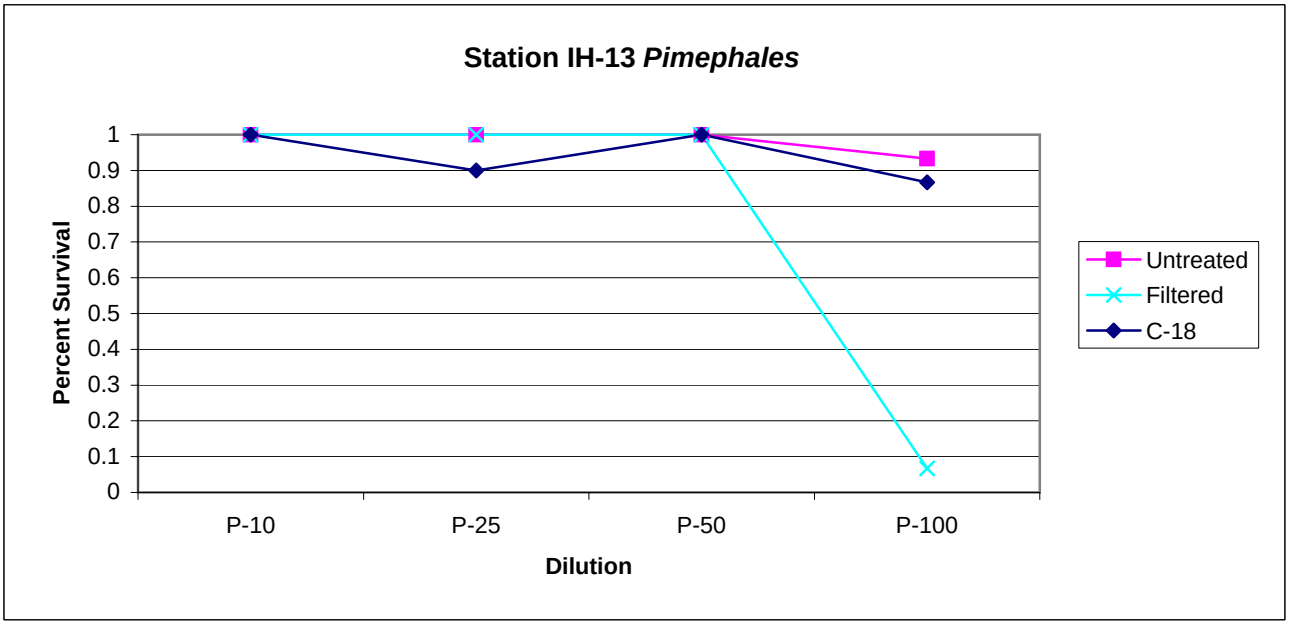
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
P-10
P-25
P-50
P-100
Dilution
Untreated
Filtered
C-18
Sodium Thiosulfate
EDTA Chelation
Low pH
High pH
Zeolite

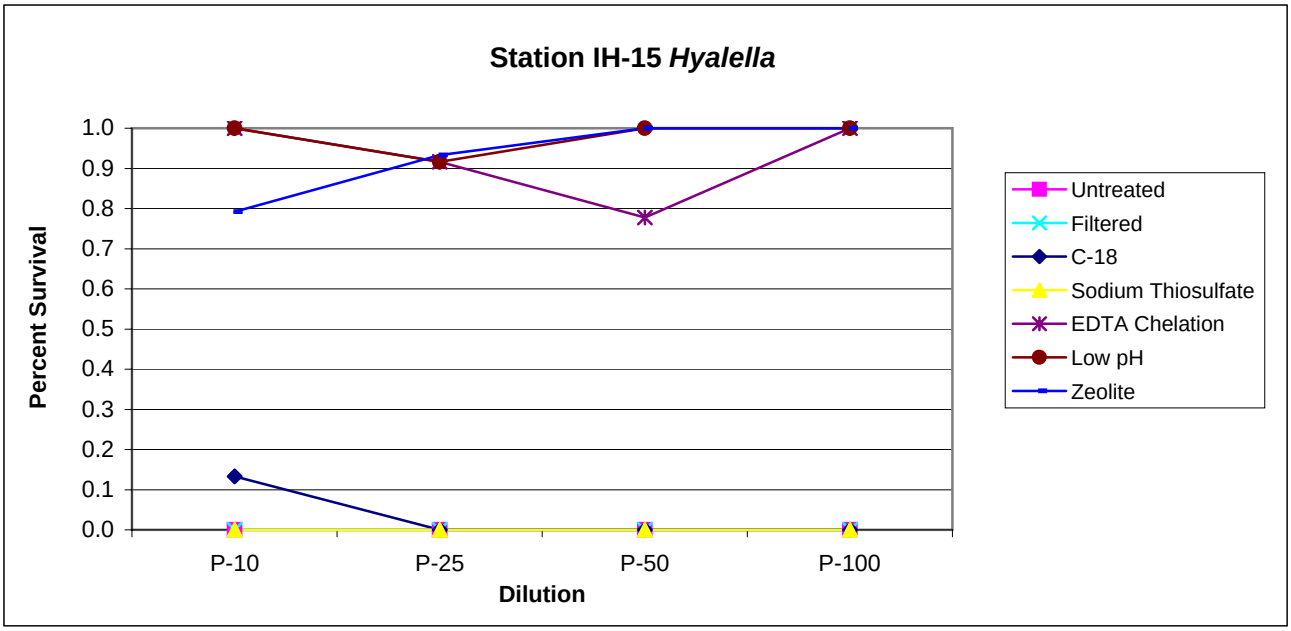

Station IH-11 *Pimephales*
Percent Survival
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
P-10
P-25
P-50
P-100
Dilution
Untreated
Filtered
C-18
Sodium Thiosulfate
EDTA Chelation

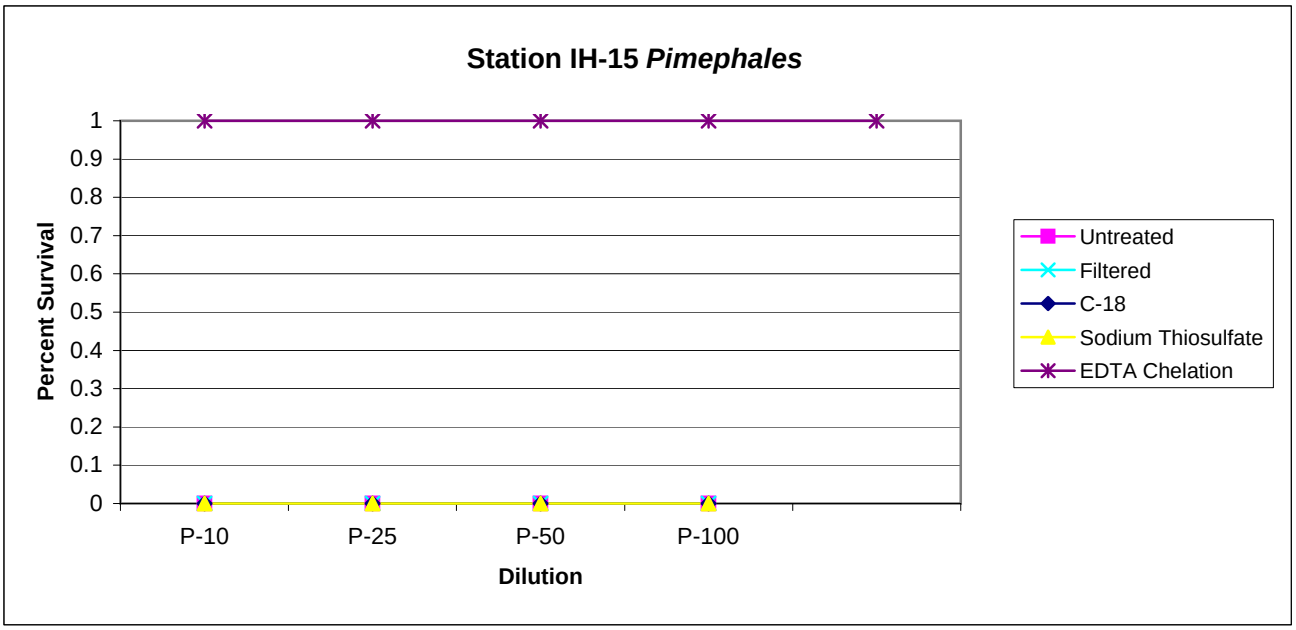

Station IH-12 *Hyalella*
Percent Survival
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
P-10
P-25
P-50
P-100
Dilution
Untreated
Filtered
C-18
Sodium Thiosulfate
Zeolite

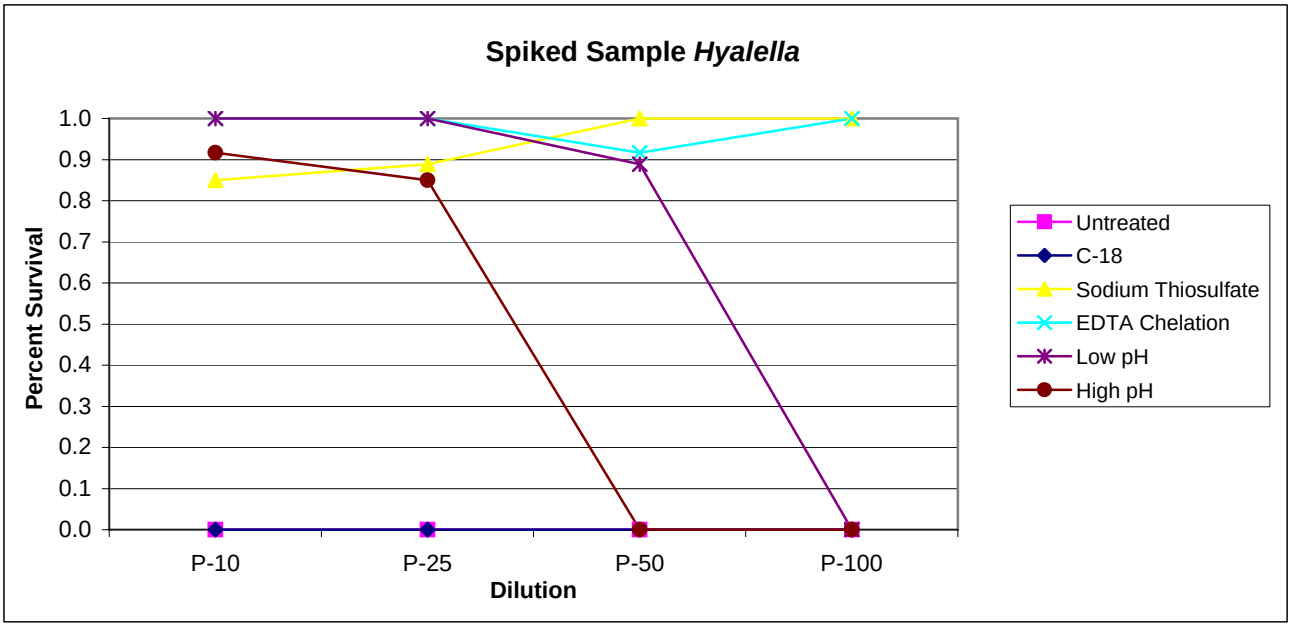

Station IH-12 *Pimephales*
Percent Survival
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
P-10
P-25
P-50
P-100
Dilution
Untreated
Filtered
C-18

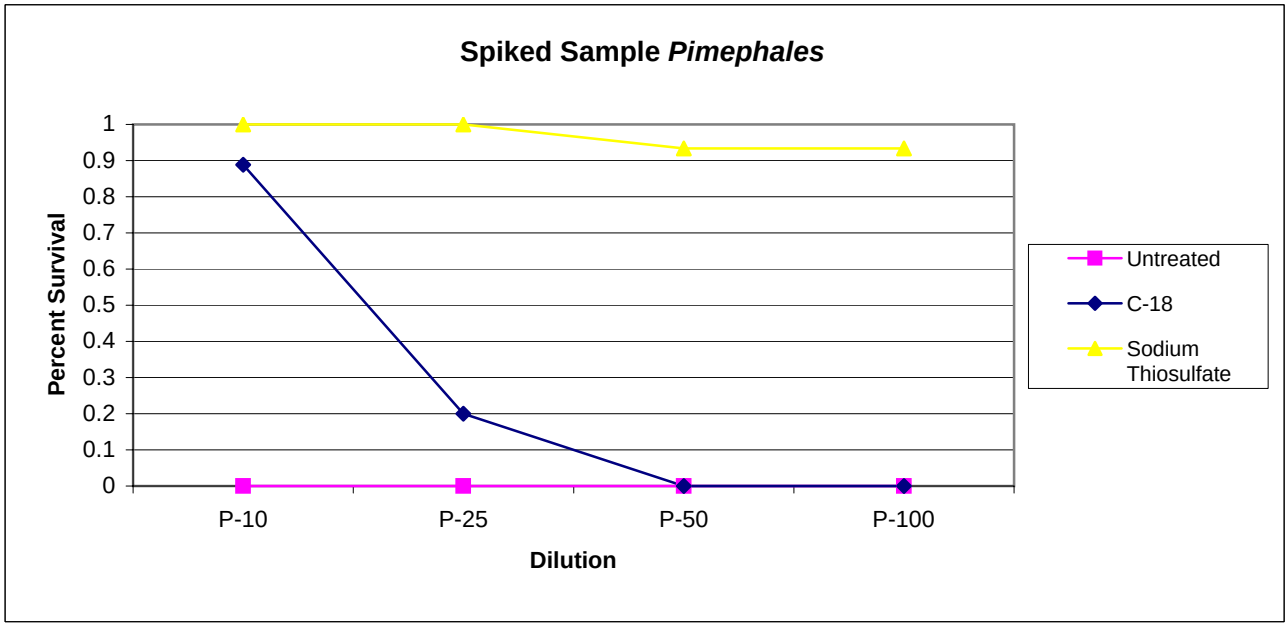

Station IH-13 *Hyalella*
Percent Survival
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
P-10
P-25
P-50
P-100
Dilution
Untreated
Filtered
C-18
Sodium Thiosulfate

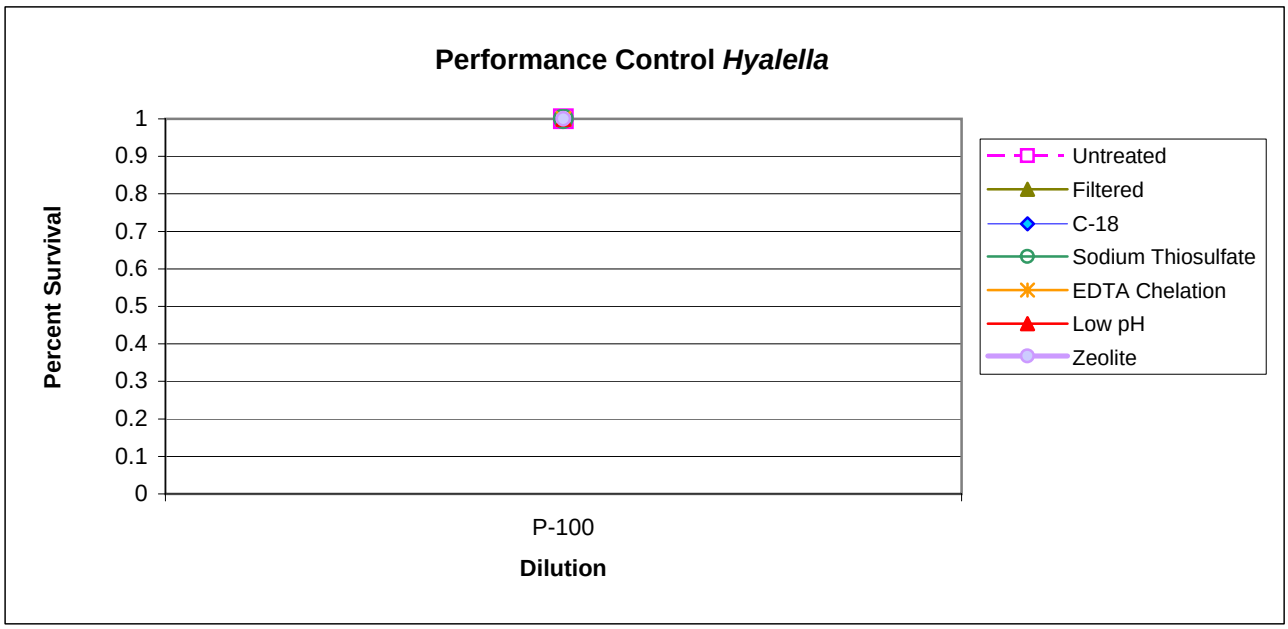

Station IH-13 *Pimephales*
Percent Survival
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
P-10
P-25
P-50
P-100
Dilution
Untreated
Filtered
C-18


Station IH-15 *Hyalella*
Percent Survival
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
P-10
P-25
P-50
P-100
Dilution
Untreated
Filtered
C-18
Sodium Thiosulfate
EDTA Chelation
Low pH
Zeolite


Station IH-15 *Pimephales*
Percent Survival
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
P-10
P-25
P-50
P-100
Dilution
Untreated
Filtered
C-18
Sodium Thiosulfate
EDTA Chelation


Spiked Sample *Hyalella*
Percent Survival
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
P-10
P-25
P-50
P-100
Dilution
Untreated
C-18
Sodium Thiosulfate
EDTA Chelation
Low pH
High pH


Spiked Sample *Pimephales*
Percent Survival
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
P-10
P-25
P-50
P-100
Dilution
Untreated
C-18
Sodium Thiosulfate


Performance Control *Hyalella*
Percent Survival
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
P-100
Dilution
Untreated
Filtered
C-18
Sodium Thiosulfate
EDTA Chelation
Low pH
Zeolite

APPENDIX B-4
Toxicity calculations – statistical summary
(Sample pages provided – full document available upon request)

Acute Fish Test-72 Hr Survival

Start Date:	10/27/00	Test ID:	IH-FLTD-4	Sample ID:	IH-FLTD-4
End Date:	10/30/00	Lab ID:	NEWPORT	Sample Type:	PORE WATER
Sample Date:		Protocol:	EPAA 91-EPA Acute	Test Species:	HA-Hyalella azteca
Comments:					

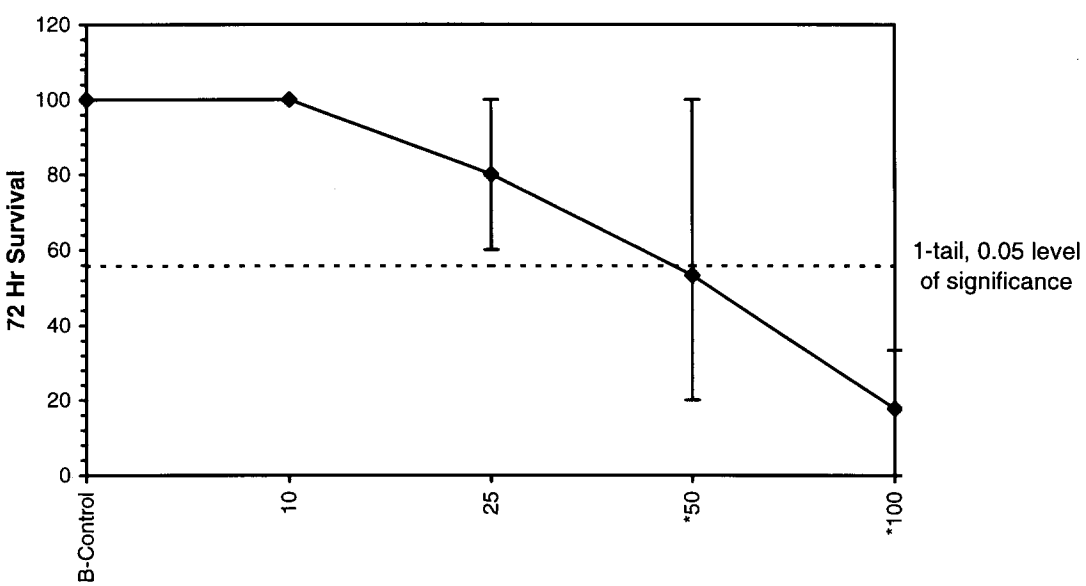
Conc-%	1	2	3
B-Control	100.00	100.00	100.00
10	100.00	100.00	100.00
25	60.00	100.00	80.00
50	100.00	20.00	40.00
100	0.00	20.00	33.33

			Transform: Untransformed					1-Tailed		
Conc-%	Mean	N-Mean	Mean	Min	Max	CV%	N	t-Stat	Critical	MSD
B-Control	100.00	1.0000	100.00	100.00	100.00	0.000	3			
10	100.00	1.0000	100.00	100.00	100.00	0.000	3	0.000	2.470	44.32
25	80.00	0.8000	80.00	60.00	100.00	25.000	3	1.115	2.470	44.32
*50	53.33	0.5333	53.33	20.00	100.00	78.062	3	2.601	2.470	44.32
*100	17.78	0.1778	17.78	0.00	33.33	94.373	3	4.582	2.470	44.32

Auxiliary Tests	Statistic	Critical	Skew	Kurt
Shapiro-Wilk's Test indicates normal distribution (p > 0.01)	0.89272	0.835	0.77665	2.22115
Equality of variance cannot be confirmed				

Hypothesis Test (1-tail, 0.05)	NOEC	LOEC	ChV	TU	MSDu	MSDp	MSB	MSE	F-Prob	df
Dunnett's Test	25	50	35.3553	4	44.3209	0.44321	3678.52	482.963	0.00439	4, 10

Dose-Response Plot



Acute Fish Test-72 Hr Survival

Start Date:	10/27/00	Test ID:	IH-FLTD-4	Sample ID:	IH-FLTD-4
End Date:	10/30/00	Lab ID:	NEWPORT	Sample Type:	PORE WATER
Sample Date:		Protocol:	EPAA 91-EPA Acute	Test Species:	HA-Hyalella azteca
Comments:					

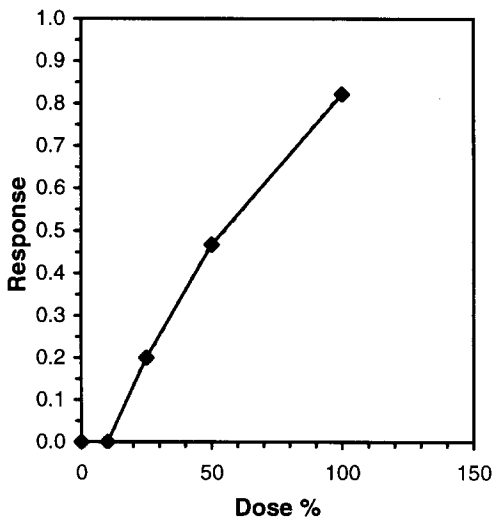
Conc-%	1	2	3
B-Control	100.00	100.00	100.00
10	100.00	100.00	100.00
25	60.00	100.00	80.00
50	100.00	20.00	40.00
100	0.00	20.00	33.33

			Transform: Untransformed					Isotonic	
Conc-%	Mean	N-Mean	Mean	Min	Max	CV%	N	Mean	N-Mean
B-Control	100.00	1.0000	100.00	100.00	100.00	0.000	3	100.00	1.0000
10	100.00	1.0000	100.00	100.00	100.00	0.000	3	100.00	1.0000
25	80.00	0.8000	80.00	60.00	100.00	25.000	3	80.00	0.8000
50	53.33	0.5333	53.33	20.00	100.00	78.062	3	53.33	0.5333
100	17.78	0.1778	17.78	0.00	33.33	94.373	3	17.78	0.1778

Auxiliary Tests	Statistic	Critical	Skew	Kurt
Shapiro-Wilk's Test indicates normal distribution (p > 0.01)	0.89272	0.835	0.77665	2.22115
Equality of variance cannot be confirmed				

Linear Interpolation (200 Resamples)

Point	%	SD	95% CL(Exp)		Skew
IC01	10.750	3.260	9.963	41.987	3.9867
IC05	13.750	3.997	9.813	43.937	1.9840
IC10	17.500	6.234	9.625	52.937	2.3274
IC15	21.250	7.189	9.438	62.102	1.8585
IC20	25.000	9.210	9.250	81.716	1.5017
IC25	29.688	9.902	8.031	82.884	1.2712
IC40	43.750	11.640	4.375	96.834	0.6612
IC50	54.688	12.667	12.008	101.667	0.4156
IC60	68.750	14.503	9.655	108.125	-0.0808
IC75	89.844				
IC80	96.875				
IC85	>100				
IC90	>100				
IC95	>100				
IC99	>100				



Appendix C.
Indian Head Sampling Locations

Appendix C-1. TIE sampling location coordinates in reference to NAD 83 datum.

Station	longitude,W, dms	latitude,N, dms
1	077 10 18.4	38 35 0.8
2	077 10 18.3	38 35 0.5
3	077 10 18.6	38 35 0.6
4	077 10 17.1	38 34 56.6
5	077 10 9.4	38 35 1.4
6	077 10 12.1	38 35 0.9
7	077 10 11.3	38 35 0.1
8	077 10 4.0	38 34 58.1
9	077 12 5.2	38 34 6.4
10	077 12 4.3	38 34 4.9
11	077 11 57.8	38 33 56.0
12	077 12 4.9	38 34 5.7
13	077 12 6.7	38 34 7.8
14	077 12 5.7	38 34 6.7
15	077 9. 4	38 35 22.5

Sta. 9,10,12-14 under tree cover; fixes are GPS only, no differential.

Appendix D.
Indian Head TIE Demonstration Work Plan

To: Ruth Owens (NFESC), Jason Speicher and David Barclift (NorthDiv),

From: Greg Tracey, Sherry Poucher (SAIC)

Date: 10/5/01

Re: Task 3: Final Work Plan for Site 1

The following Work Plan for the Toxicity Identification Evaluation (TIE) Demonstration to be conducted with sediments from the Naval Surface Warfare Center at Indian Head, Maryland represents DP 3.3 under Task 3 of TIE Demonstration Project (Contract Number: N47408-00-C-7123). A draft Work Plan (DP 3.1) was submitted on 10 August, and the minimal revisions recommended by NORTHDIV, NFESC, and Navy site representatives have been incorporated. A written response to comments from the draft Work Plan (DP 3.2) was not requested because we concurred with the clearly stated recommended revisions. A letter of concurrence from Simeon Hahn (BTAG) was received on 6 October, indicating the project should proceed, as planned.

As always, please let us know if you have a questions or comments. Cordially,

Greg Tracey
Sherry Poucher
SAIC
221 Third Street
Newport, RI 02840
Phone: 401.847.4210

WORK PLAN FOR:

CONDUCT OF NAVY SEDIMENT TOXICITY IDENTIFICATION EVALUATION DEMONSTRATION:

INDIAN HEAD
NAVAL SURFACE WARFARE CENTER

SUBMITTED TO:

DEPARTMENT OF THE NAVY
NAVAL FACILITIES ENGINEERING SERVICE CENTER
NCBC CODE 27162 BUILDING 41
1000 23RD Avenue
Port Hueneme, CA 93043-4410

SUBMITTED BY:

SCIENCE APPLICATIONS INTERNATIONAL CORPORATION
221 THIRD STREET
NEWPORT, RI 02840

IN RESPONSE TO:

NAVY BAA N47408-97-D-0410

10 October 2000

Final

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1.0 INTRODUCTION

The Naval Surface Warfare Center at Indian Head, Maryland, a location with tidal fresh, potentially contaminant-impacted habitats, was chosen as one of two sites that will be evaluated as part of the Sediment Toxicity Identification Evaluation (TIE) Demonstration project for the Naval Facilities Engineering Service Center. The Technical Proposal for the Demonstration Project was submitted and approved in March 2000 (SAIC 2000a). Indian Head was chosen as a Demonstration site because it conforms with the principal site-selection criteria developed for the project designed to resolve ecological risk concerns:

1. An identified need exists for information that may clarify the source of apparent toxicity in creek sediments adjacent to Site 42 (Olson Road Landfill). Thus, results from the TIE should help to resolve regulatory uncertainties and site management decisions.
2. The study site presents a unique case study in relation to environmental and contaminant characteristics relative to the other chosen site. Thus, the TIE program should demonstrate applicability in diverse habitat conditions, and serve to address uncertainties with regard to the principal toxic agents that may be found across a wide variety of navy sites.

The Program Team involved in addressing remediation at the site includes the primary technical team (SAIC), the oversight/liaison team (Navy Northern Division), the Installation Restoration support team (EFAChes IR staff and contractors), the Activity Team (Indian Head NSWC staff) and the Regulatory Team (Region III Biological Technical Assistance Group (BTAG)). The Program Team is committed to a close collaboration with the TIE effort to assure successful and efficient study designs and sampling efforts.

1.1 Background and Objectives

Sufficient data were presented in a Remedial Investigation report (Tetra Tech NUS 1999a) to propose that two locations at Indian Head are appropriate for the TIE Demonstration: Site 42, known as the Olsen Road Landfill and Site 39/41 where an Organics Plant and Scrap Yard are located. The principal identified Contaminant of Concern (COPC) was silver.

A remedial excavation to remove silver-contaminated soils from two swales that drained into Site 42 was completed in 1994, and resulted in reductions to below the 10 mg/kg action level for silver (a value that marks the concentration distribution for 99% of sediments in the National Sediment Inventory; EPA 1997). However, silver was measured at concentrations above the action level in Site 42 sediments, and was identified by the BTAG as the Chemical of Potential Concern (CoPC) for aquatic receptors at this site. Recently, bulk sediment toxicity tests have been conducted with Site 42 samples (Tetra Tech NUS 1999b), and toxicity was demonstrated in each of the thirteen representative sediments. Ammonia has been implicated as a confounding factor contributing to observed toxicity (Tetra Tech NUS 1999b), and other contaminants have not been conclusively excluded as contributors to toxicity (Tetra Tech NUS 1999a). The Indian Head Remedial Investigation also found silver concentrations at Sites 39/41 in the same range or higher than in Site 42, along with some additional COCs that were not identified for Site Area 42

(Tetra Tech NUS 1999a). The Remedial Investigation Report characterizes Sites 39/41 and Site 42 using chemistry and physical data from an historic site inspection (E/A&H 1992; E/A&H 1994) and from a 1997 survey conducted for the Remedial Investigation and indicated mercury, nickel and nitrocellulose were included as CoCs for Site 39/41, in addition to silver.

The objectives of the proposed Phase 1 TIE study are to provide data to identify sources and magnitude of toxicity associated with contaminants at the site as well as to characterize the extent to which confounding factors (e.g., ammonia) are potentially involved in the toxic response. The sampling design derived to meet these objectives is discussed in Section 2; the technical approaches for field and laboratory analysis procedures are discussed in Section 3.

2.0 SAMPLING DESIGN FOR THE INDIAN HEAD SITE

The choice of sampling locations within Site 39/41 and Site 42 is specifically directed at evaluating the potential contribution of silver relative to other sources of toxicity to aquatic receptors at the Indian Head sites. For purposes of the TIE Demonstration, the stations were selected for one or more of the following characteristics:

- Bulk sediment silver concentrations that exceed benchmarks for potential/probable effects;
- Divalent metal concentrations (SEM) that enhance potential for silver toxicity;
- Confounding factors (e.g., TOC, AVS) that may affect chemical bioavailability;
- Confounding factors (e.g., NH_4) that directly contribute to toxicity;
- Contaminants other than metal CoCs (e.g., total petroleum hydrocarbons, nitrocellulose) that exceed benchmarks and hence may contribute to toxicity;
- Spatial variation that might reflect novel environmental conditions or CoC distributions that may represent gradients in chemical availability.

2.1 Strategy for Evaluating Potential Toxicity of Silver-contaminated Sediments

Many variable characteristics of sediments are known to mediate toxicity associated with silver contamination beyond the absolute silver concentration. Acid Volatile Sulfides (AVS), dissolved and particulate organic carbon, chlorides, ammonia, presence of other heavy metals and enzymatic biological processing within organisms are the major factors that have been reviewed in a recent issue of Environmental Toxicology and Chemistry (Volume 18:1 January 1999). Though progress has been made, current understanding of the mechanisms that govern bioavailability and toxicity of silver is still not well resolved.

The following discussion summaries the state-of-knowledge with regard to silver bioavailability and data evaluation techniques used in selection of locations for TIE evaluation.

Bulk sediment concentrations. The correlative benchmark value representing threshold concentrations for potential effects of silver in bulk sediment (4.5 µg/g dry weight) is based on the Upper Effects Threshold concentration observed for the *Hyallela azteca* bioassay (NOAA 1998). The benchmark is relevant to the Indian Head site as it is based on a freshwater species

that can be expected to occur in the region. Still, it is the only published benchmark for silver in freshwater sediments, and thus it is difficult to assess the degree of protectiveness that this benchmark affords. It should also be noted that other sediment contaminant benchmarks for silver that are derived from field measurements frequently reflect the co-occurrence of multiple contaminant, and often these co-contaminants are at very elevated levels. The skewing is because more data have been reported for highly contaminated sites than for sites with low contaminant issues. With these uncertainties in mind, the sediment concentrations were compared against the UET value for purposes of selecting stations representing *potential* silver toxicity.

Recent studies have shown that toxicity in laboratory silver-only spiking experiments tends to occur only at concentration much higher than sediment benchmark values (Call et al. 1999; Berry et al. 1999; Rogers et al. 1997). This discrepancy may be in part due to other collocated contaminants or confounding factors in the benchmark samples that contributed to toxicity. The study of Call et al. (1999) was deemed applicable to Indian Head sediments given that it focused on freshwater sediments with AVS and TOC concentrations similar to the candidate TIE demonstration stations with highest silver concentrations. Briefly, the study found reduced growth of the midge, *Chironimus tentans* when sediments were in the 200-500 µg/kg range (Table 2-1). Hence, sediment concentrations were also compared against the 200 µg/g value for purposes of selecting stations representing *probable* silver toxicity.

Simultaneously Extracted Metal (SEM) concentration. Research into the bioavailability and toxicity of metals (DiToro et al. 1992) has found that for some metals, sulfides (measured as Acid Volatile Sulfides, AVS) in sediments can act as an important binding compound that can prevent toxicity as long as the quantity of AVS is in excess of the total amount of metals (measured as SEM). Sulfides are a common constituent of organic-rich sediments that do not have prolonged exposure to oxygen in the water column (e.g., hypoxic). As for the bioavailability of silver in particular, Berry et al. (1999) demonstrated that this metal does respond like other SEM metals in binding to AVS, in that, when the metal occurs in excess of the available AVS concentration (Ag/2-AVS), toxicity appears to be accurately predicted in several cases. Hence, available SEM:AVS data was used to identify locations of potential metal toxicity, including silver.

Until very recently, silver was not typically included in the SEM measurements. However, due to similarity in the chemical extraction methods for SEM and typical bulk sediment metals analysis (both are 10% nitric acid digestion methods), the concentration of SEM can be roughly estimated to be equal to the corresponding bulk sediment concentration. In addition, due to the absence of site-specific information regarding AVS and organic carbon concentrations, it is possible to roughly estimate potential for metal-binding by considering measured concentrations of iron. As the principal form of AVS is iron monosulfide (FeS), iron concentration in bulk sediment may be an indicator of AVS binding capacity. It is acknowledged that the degree to which iron is present as the more stable pyrite form (FeS_2) confounds the direct interpretation of iron as a limiting factor, but for the purposes of station selection for TIE demonstration, this uncertainty was deemed tolerable. Hence, estimated SEM:AVS data was used to identify locations of potential metal toxicity.

Confounding factors affecting bioavailability and toxicity. In the historical and recent surveys conducted at the Indian Head site, sediment constituents were measured to varying degrees, resulting in uncertainty with regard to the potential for toxicity of silver vs. confounding factors. A limited number of samples were analyzed for organic carbon, AVS or ammonia. Still, the available data indicate that locations generally characterized by lower organic carbon and AVS or alternatively, high ammonia, have the greatest potential for toxicity. This supports a hypothesis of low binding potential for the chemical to the sediment matrix and therefore an enhanced potential for toxicity to aquatic organisms at the reported concentrations. Hence locations of varying TOC, AVS and ammonia were evaluated to select stations that address site-specific effects on potential contaminant toxicity.

Published effect concentrations for freshwater amphipods exposed to ammonia are not available. However, for marine amphipods, concentrations where effects were not observed in ammonia-only toxicity tests (i.e., no observable effect concentrations (NOECs)) ranged between 30 and 60 mg/L for total ammonia and between 0.4 and 0.8 mg/L un-ionized ammonia (U.S. EPA 1994). In a TIE evaluation conducted for the Army Corp of Engineers with pore waters from Blackstone River, Massachusetts sediments, *Hyallela* survival was unaffected by total ammonia concentrations up to 25 mg/L or 0.5 mg/L unionized ammonia (SAIC 2000b). In the same study, SAIC data demonstrated a strong correlation between fathead minnow (*Pimephales promelas)* larval mortality and pore water ammonia concentrations, suggesting that it may be useful to pair this species with *Hyallela* in the Indian Head TIE demonstration. Available ammonia data corresponding to observed bulk sediment toxicity of Indian Head site sediments is all below 25 mg/L, but uncertainty regarding pH over the course of the test makes calculations of the more toxic un-ionized fraction unreliable.

Contaminants other than metal COCs. A limited number of organic contaminants were identified in Indian Head sediments at concentrations that are above known benchmarks. Potential risks for acute toxicity to aquatic receptors from these compounds should not be dismissed from the TIE study. As with the confounding factors associated with metal toxicity, organic contaminants in sediments at Indian Head were measured to varying degrees, resulting in uncertainty with regard to the potential for toxicity. Measurements reported for Total Petroleum Hydrocarbons (TPH) at two locations (119 and 215 µg/kg) that were included in the 1994 survey for Site 41 warrant consideration. They exceed values that have been used as screening levels applied to evaluate contamination at ecologically protected airport-associated sites, and are also associated with measured Polycyclic Aromatic Hydrocarbon (PAH) measurements that exceed the NOAA ERL values for high molecular weight PAHs. Lacking more complete information regarding the individual constituents of the TPH at the Indian Head sites, it is prudent to include samples that represent this unique type of contamination in the TIE Demonstration. The result will be a better characterization of the constituents of the TPH, along with organic carbon levels that drive bioavailability, and ultimately, their contribution to potential toxicity of the organic contaminant fraction.

Lastly, another potentially important group of contaminants represented in the chemical profiles presented in the Remedial Investigation is explosives. In particular, some unusually high values

for nitrocellulose were reported at Site 39, with a maximum of 1,580,000 µg/Kg. While no data are available regarding the potential acute effects of this compound on aquatic receptors, production of explosives at the site warrants consideration with regard to 'energetic' constituents. The high nitrocellulose value serves as a marker for this group of compounds that represents a highly uncertain risk.

Spatial distributions. Another important consideration in selecting stations for the TIE Demonstration at Indian Head is that characterizations of Sites 39/41 and Site 42 have demonstrated a high degree of spatial variability, reflecting multiple sources of contamination as well as a range of factors that affect bioavailability. Therefore, the distribution of station locations was chosen not only to incorporate the greatest potential sources of toxicity, but also to broadly assess the potential factors governing toxicity.

2.2 Rationale for Selection of Specific Sites

Table 2-2 describes each of 15 proposed locations in terms of the characteristics that led to its selection, with particular emphasis on factors that may influence toxicity associated with elevated silver and other heavy metals. The stations have been chosen not only to maximize opportunities to observe and characterize potential toxicity from silver, other COC and confounding factors, but also to provide a representation of the varying contaminant signatures and sediment characteristics that occur across Site 39/41 and Site 42. The locations of each station, coded to represent the apparent CoCs or confounding factors, are displayed in Figure 2-1. A rationale for the selection of each individual recommended station is presented in Table 2-3.

3.0 TECHNICAL APPROACH

In a TIE investigation, the physical/chemical properties of sediment pore water samples are manipulated in order to alter or render biologically unavailable generic classes of chemicals (U.S. EPA 1991). Because sediments posing potential risks are usually toxic to aquatic organisms, fractions exhibiting toxicity reveal the nature of the toxicant(s). Depending upon the responses, the toxicant(s) can be tentatively categorized as having chemical characteristics of non-polar organics, cationic metals or confounding factors such as ammonia (U.S. EPA 1996).

Procedures for conducting specific TIE steps developed by EPA (1996) describing specific methodologies and QA/QC procedures form the basis for the proposed technical approach. SAIC has improved on the EPA approach by applying sequential testing of fractions and documentation of cumulative removal up to and including the production of a completely non-toxic samples (Figure 3-1). Using the sequential approach, absence of residual toxicity provides a clearer demonstration that all the relevant chemical exposures in a sample can be adequately accounted for. SAIC's approach has been successfully demonstrated at the Naval Submarine Base-New London, CT at an IR site (Goss Cove) for Northern Division (Navy RPM News 1999; SAIC 1999). Prior remedial investigation and risk assessment studies for the site have suggested actionable risk although considerable uncertainty existed as to the contaminants responsible for risk. The application of the improved TIE process revealed that ammonia (a ubiquitous non-CoC

sediment constituent) and not the conventional sediment contaminants (e.g., PAHs, metals) was responsible for the risk.

For the Indian Head site Demonstration, SAIC will conduct sediment sampling, bulk toxicity and pore water TIE testing, and chemical analyses. The following sections describe the design and methodology for sample collection, the rationale and methods for laboratory testing, chemical analysis and data interpretation.

3.1 Field Sampling

Station positioning. To address the TIE data needs, the 15 selected stations will be sampled for chemical and toxicological characterization. Precision navigation for each sampling location will be achieved through the use of differentially corrected Global Positioning System (DGPS) data, where it is deemed reliable. A Garmon GPS receiver will be used to provide survey location positioning data in the horizontal control of North American Datum of 1983 (NAD 83) for all three phases of field operations. At some sampling stations, vegetative cover may preclude use of GPS. At those stations, markers identifying station locations from previous surveys will be used.

Sediment collection and handling. A 0.04 m² Young-modified van Veen and or mini Ponar grab sampler(s) will be used to collect undisturbed surface sediment to a penetration depth comparable to that used in the Remedial Investigation. The stainless steel grab sampler is first cleaned with an Alconox solution, site water rinsed, alcohol rinsed, and acid rinsed, followed by a final site water or distilled water rinse before use at each station. Clean polyethylene scoops may also be used to collect sediment at shallow sites. Photographs will be taken of a representative grab using a flash camera to illustrate lithographic features (e.g., redox depth, recent depositional patterns). Five gallons of sediment will be collected into pre-cleaned polyethylene buckets at each station for transport to a shore-side location. Compositing and sub-sampling into pre-cleaned containers will take place for various measurements at the sub-contractor's site where bulk sediment assays are to be performed. Samples are subsequently packed on blue ice and shipped for overnight delivery to selected chemical analysis laboratories. Full chain of custody procedures will be followed.

3.2 Toxicity Characterizations

Bulk sediment toxicity characterization. Phase I TIE methods are designed for acutely toxic samples and are based on the use of small test organisms. The 10-day *Hyalella azteca* test (Table 3-1; U.S. EPA 1994) will be used. It was previously chosen for bulk sediment tests at Site 42 and toxicity was observed. *Hyallela* also tolerates the full range of grain sizes that might be encountered at the study sites.

The tests will be conducted with eight replicates and will include a performance control sediment from a pristine freshwater site with known sediment characteristics, such as the sediment that is routinely provided by Chesapeake Cultures for *Hyallela* testing.

TIE sample selection/porewater extraction. Upon completion of the 15 bulk sediment toxicity tests, the ten most toxic sediment samples will be selected for pore water extraction using the syringe method (Winger and Lassier 1991) and for subsequent chemical analysis of metals according to National Oceanic and Atmospheric Administration (NOAA) National Status and Trends Program protocols (NOAA 1997). Also, treatments for TIE tests will include pore water extracted from the performance control sediment. Finally, water-only control exposures and dilution water will utilize clean, alkalinity and hardness-adjusted fresh water (filtered to 10*u*) in all TIE tests, unless alternative control water is deemed more suitable by SAIC.

TIE procedures. The proposed Phase I TIE characterization will consist of the following recommended characterization steps or tiers: (1) Baseline Toxicity Test; (2) C_{18} column extraction; (3) sodium thiosulfate; (4) Ethylenediamine Tetraacetic Acid (EDTA); (5) graduated pH; and (6) zeolite. Guidelines for TIE data interpretation are presented in U.S. EPA (1991) and are summarized below:

1. **Baseline Toxicity Test**: Toxicity in exposures to whole pore water indicates the presence of bioavailable chemicals or other confounding factors (e.g., ammonia). Good survival in these exposures indicates that toxicity observed in the solid phase test is due to a factor(s) that is solely associated with the particle phase of the sediments. Toxicity due to extremes of sediment grain size (e.g., extremely coarse or fine) is an example of this type of effect.

1a. **Filtration.** Prior to C_{18} extraction, the pore water may be filtered with 0.45µm filter paper to remove particulates that would otherwise consume sites on the extraction column. In addition, toxicity tests conducted on the pre- and post-filtered fraction will allow for expression of any potential toxicity associated with large colloids or particulates trapped on the filter.

2. **C_{18} column extraction**: Pore water samples will be subjected to C_{18} extraction to remove organic compounds and metals that are relatively non-polar (U.S. EPA 1991). A non-toxic response in these exposures will indicate the potential role of organic compounds as the sole contributor to toxicity of pore waters. A fully toxic response will indicate that organic compounds are not responsible for observed pore water toxicity. A partial reduction in toxicity would define a joint toxic action by organic compounds and other factors.

3. **Sodium thiosulfate**: Sodium thiosulfate ($Na_2S_2O_3$) will be used to reduce oxidants such as chlorine, ozone, chlorine dioxide, mono and dichloramines, bromine, iodine, manganous ions, and some electrophilic organic chemicals and to remove cationic metals including Cd^{2+}, Cu^{2+}, Ag^{1+}, and Hg^{2+} in the pore water samples (U.S. EPA 1991). Reduced toxicity or a non-toxic response will indicate oxidants or cationic metals as contributors to toxicity.

4. **EDTA chelation**: Samples will be subjected to EDTA chelation to remove divalent cationic metals (i.e., Al^{2+}, Ba^{2+}, Fe^{2+}, Mn^{2+}, Sr^{2+}, Cu^{2+}, Ni^{2+}, Pb^{2+}, Cd^{2+}, Co^{2+}, and Zn^{2+}) (Schubauer-Berigan et al. 1993a; U.S. EPA 1991). A non-toxic response or a partial reduction in toxicity indicates metals as a toxic component of the pore water. A fully or partially toxic response

indicates that something other than divalent cationic metallic compounds is a contributor to sediment toxicity.

5. **Graduated pH**: In this procedure, sample pH is manipulated to determine if pH dependent toxicants such as speciated metals, ammonia, hydrogen sulfide, cyanide and some ionizable organic compounds (e.g., pentachlorphenol) are responsible for observed toxicity (Schubauer-Berigan et al. 1993a; Schubauer-Berigan et al. 1993b; U.S. EPA). For instance, if sample toxicity increases with increasing pH, toxicants such as ammonia are suspected. Conversely, if sample toxicity increases with decreasing sample pH, toxicants such as hydrogen sulfide are suspected. Typical pH adjustments include 1.5 pH units above and below ambient pH (e.g., pH 6 and pH 9, for ambient pH = 7.5 ; or pH 6 and pH 7 for ambient pH 8).

6. **Zeolite treatment**: Samples will be manipulated using a zeolite cation exchange resin to remove ammonia (Ankley et al. 1990; Besser et al. 1998; Jop et al. 1991; Van Sprang and Janssen 1997). A non-toxic sample will indicate the presence of ammonia as contributing to pore water toxicity in the precursor sample. A partial toxic response is not expected since organics, metals, oxidants, hydrogen sulfide, pH-dependent toxicants, and ammonia will have been sequentially removed from the samples.

The pore water will be manipulated according to the sequential extraction scheme shown in Figure 3-1. The test species are appropriate for the site and are also amenable to TIE testing protocols. In addition to the ten site sediments, the TIE protocol requires that pore water from a performance control (i.e., clean freshwater) be evaluated. In addition, a clean freshwater sample spiked to produce toxic concentrations of a metal CoC (e.g. silver) and an organic contaminant may be included as a positive control, for a total of 12 treatments. One freshwater control will be run in parallel to each manipulation. Thus, 84 toxicity tests (12 samples x 7 treatments) will be performed for each species 3.2).

Biological Tests. For the purposes of this demonstration, it is assumed that the two species being tested will include an amphipod and a fish and that the seven manipulations as described above (pH = two treatments) will be performed. For riverine sites such as the Indian Head study areas, the freshwater amphipod *Hyallela* and the fathead minnow *Pimephales promelas* are recommended species.

Toxicity tests will generally be performed as described by U.S. EPA (1993) and modified in Ankley et al. (1991), Jop et al. (1991), and U.S. EPA (1991b). The amphipod method described in U.S. EPA (1996) and Ho et al. (1997) and the larval fish method described in U.S. EPA (1996) will be used. Standard toxicity test methods will be adapted for use in TIEs to accommodate reduced exposure volume (EPA/600/R-96-054). For this program, procedures for marine TIEs using the amphipod *Ampelisca abdita* will be adapted for *Hyallela* and the fish test using *Pimephales* will be performed as described US EPA 1991 (Table 3-3). For each method, animals will be obtained from laboratory cultures of commercial vendors. A dilution series of four test concentrations (10%, 25%, 50%, 100% porewater) will be performed.

3.3 Chemical Analyses

Laboratory analysis of metal, AVS and organic contaminants in sediment, and metals in porewater will be conducted according to methods outlined in the NOAA Status and Trends Program (NOAA 1998). Sulfides in pore water will be measured using either the iodometric or electron specific method recommended by the American Public Health Association for analysis of waste waters (American Public Health Association, 1995) Multi-elemental techniques such as these provide sensitive results with a high degree of accuracy and precision (NOAA 1998). Recommended target analytes are listed in Table 3-4.

The percent moisture of sediment samples are determined prior to sample extraction or analysis and sample volumes are adjusted to achieve desired quantitation limits (dry basis) for all sediment samples regardless of the high moisture content of the samples. Samples are to be maintained at 4 ±2 ^{o}C) consistent with the Contract Laboratory Program (CLP) instruction procedures for sample storage. All sample results will be reported on a dry weight basis according to the methodology described by Sweet and Wade in the NOAA Status and Trends Report (NOAA 1998).

Quality control samples are processed along with each batch of samples. Adherence to the specified QA/QC procedures is particularly important in that it provides a basis for comparing data among different methods and different laboratories.

Ten surface sediment samples from the fifteen proposed sampling stations will be selected for detailed chemical analysis of pore water metals. Split samples of pore water taken for toxicity analysis will be prepared for chemical analysis.

For QA/QC purposes control water will be spiked with a known concentration(s) of a site-related CoC. For this study, the control water will be spiked with 1000 µg/L silver, and also 200 µg/L fluoranthene. This sample will be subjected to the seven TIE manipulations, and chemical analyses will be performed on pre-and post-manipulation subsamples.

Finally, in order to assess the bioavailability of these contaminants, measurements are needed of the dissolved organic carbon (DOC) in the pore water samples (EPA Method 415.1) and the total organic carbon (TOC) of the sediments (EPA Method 415.1).

3.4 Data Analysis and Reporting

The LC_{50} values (calculated using ToxCalc [version 4.0.8] from Tide Pool Scientific Software) will be evaluated for conformance within the normal bounds of variance applied for these tests. The supplier of test organisms will also be required to supply results from recent reference toxicity tests. Results from each sediment or pore water exposure will be evaluated using a one-way, unpaired t-test (alpha = 0.05) assuming unequal variance for statistical calculations to determine differences from controls.

A report documenting data results and conclusions produced from the TIE investigation will be produced. From this report, SAIC will be prepared to present the results of the site investigation to the regulators, BTAG, and RAB members.

4.0 PROJECT ORGANIZATION AND RESPONSIBILITIES

SAIC will be responsible for the overall technical and fiscal management of the project including the field collection and laboratory analyses activities described below. NFESC personnel will be responsible for the contract management, supportive technical oversight and coordination among federal and state regulatory agencies, if needed. NORTHDIV personnel will be responsible for additional technical oversight and project management dealing with on-site activities and coordination between SAIC, NFESC, and Navy site representatives.

Key Navy personnel for this project are:
Ruth Owens, NFESC Technical Point of Contact (POC)
Jason Speicher, NORTHDIV Technical Point of Contact (POC)
Dave Barclift, NORTHDIV Technical Point of Contact (POC)
Robert Sadorra, Remedial Project Manager (EFACHES)
Shawn Jorgensen, Indian Head Facility Contact

Key SAIC personnel supporting the project include:
Gregory Tracey, Program Manager
Sherry Poucher, Lead for Toxicological Analyses
Michael Cole, Lead for Field Sample Collection

5.0 DELIVERABLE PRODUCTS AND SCHEDULE

A summary of Deliverable Products (DP) and schedule are summarized below. All deliverable products are considered accepted upon delivery. SAIC will prepare all reports and products in SAIC-specified format.

5.1 Field Sampling/Laboratory Analysis

SAIC will conduct field sampling and laboratory analyses according to this work plan.

- Deliverable Product: Completion of field sampling as documented in monthly progress reports. Due Date: 4 weeks after completion of final work plan (DP 4.1; 17 October 2000).
- Deliverable Product: Completion of laboratory analyses as documented in monthly progress reports. Due Date: 4 weeks after completion of field sampling (DP 4.2; 14 November 2000).

5.2 Site Report Preparation

SAIC will prepare a draft and final TIE site report (50-100 pp text). Electronic copies of the report will be sent to all Navy personnel and Navy Contractors involved with each project, as designated by the NORTHDIV POC. Up to ten copies of the draft and final report, including all appendices, photographs, and graphics will be distributed. One electronic copy of the final report will also be submitted on 3.5" disk PDF format.

- Deliverable Product: Draft Site 1 TIE Report.
  Due date: (DP 5.1, 12 December 2000).
- Deliverable Product: Final Site 1 TIE Report, incorporating comments on Draft report.
  Due date: 4 weeks after receipt of all comments on Draft Report (DP 5.2; 6 February 2001).

6.0 TECHNICAL ASSUMPTIONS

6.1 Assumptions regarding Field and Laboratory Activities.

- Field operations for the site will be completed during only one mobilization. For each sampling program, SAIC has included an assumption of one stand-by day to allow for inclement weather and/or other unforeseen complications with materials or equipment.
- The Navy will assist in relocation of sampling sites selected for TIE evaluations.
- SAIC will subcontract all necessary chemical and toxicity analyses in accordance with the TIE work plan.
- All laboratory chemical analyses conducted by SAIC will be performed in accordance with NOAA NS&T (1998) protocols. Laboratory data reports will be included in the TIE report and contain detail sufficient for EPA Reduced Level III data validation.

6.2 Assumptions regarding Deliverable Reports.

- The evaluation report will be provided in two iterations: Draft, and Final.
- Draft and Final Reports will be sent to 1) the facility environmental representative, 2) the Navy's IR RPM for the facility, 3) the NFESC POC, 4) the Northern Division POC, and 5) to regulators and trustees as designated by the Northern Division POC. Ten copies of the report are assumed for each deliverable.
- In addition to the hard copy distribution of the final report, a copy of the final report will be provided in PDF format to the Navy IR RPM and NFESC POC.
- The SAIC PM (and supporting personnel as deemed necessary by SAIC) will attend one technical meeting coupled with a Restoration Advisory Board (RAB) meeting to present the results of the investigation and SAIC's recommendations.

7.0 QUALITY ASSURANCE

The letter of transmittal for the report submission will include a certification that the submission has been subjected to SAIC's own review and coordination procedures to insure: (a) completeness for each discipline commensurate with the level of effort required for that submission, (b) elimination of conflicts, errors, and omissions, and (c) the overall professional and technical accuracy of the submission.

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Figure 2-1. Recommended Stations for the Indian Head TIE Demonstration.

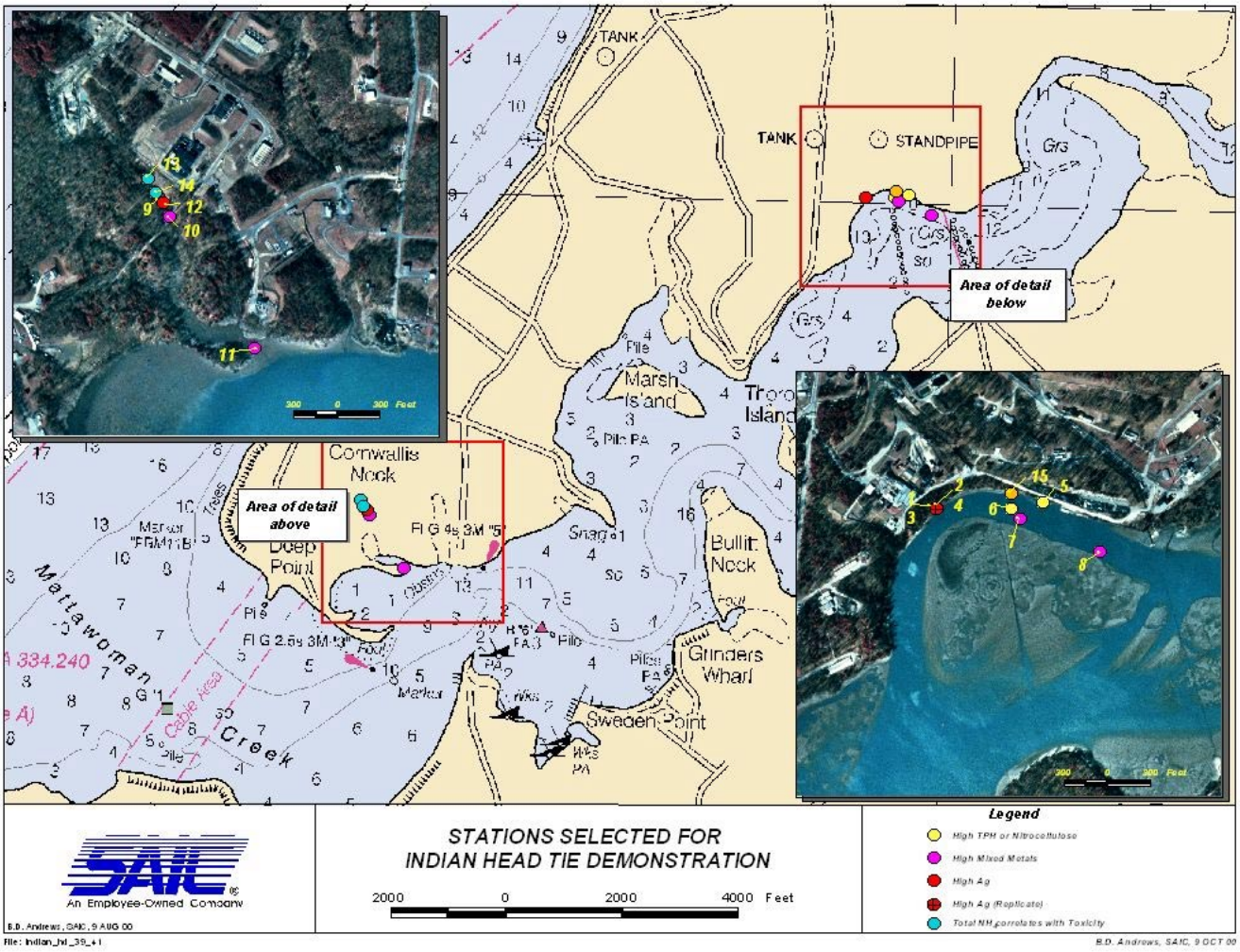

Figure 3-1. Toxicity Identification Evaluation porewater chemical fractionation procedure.

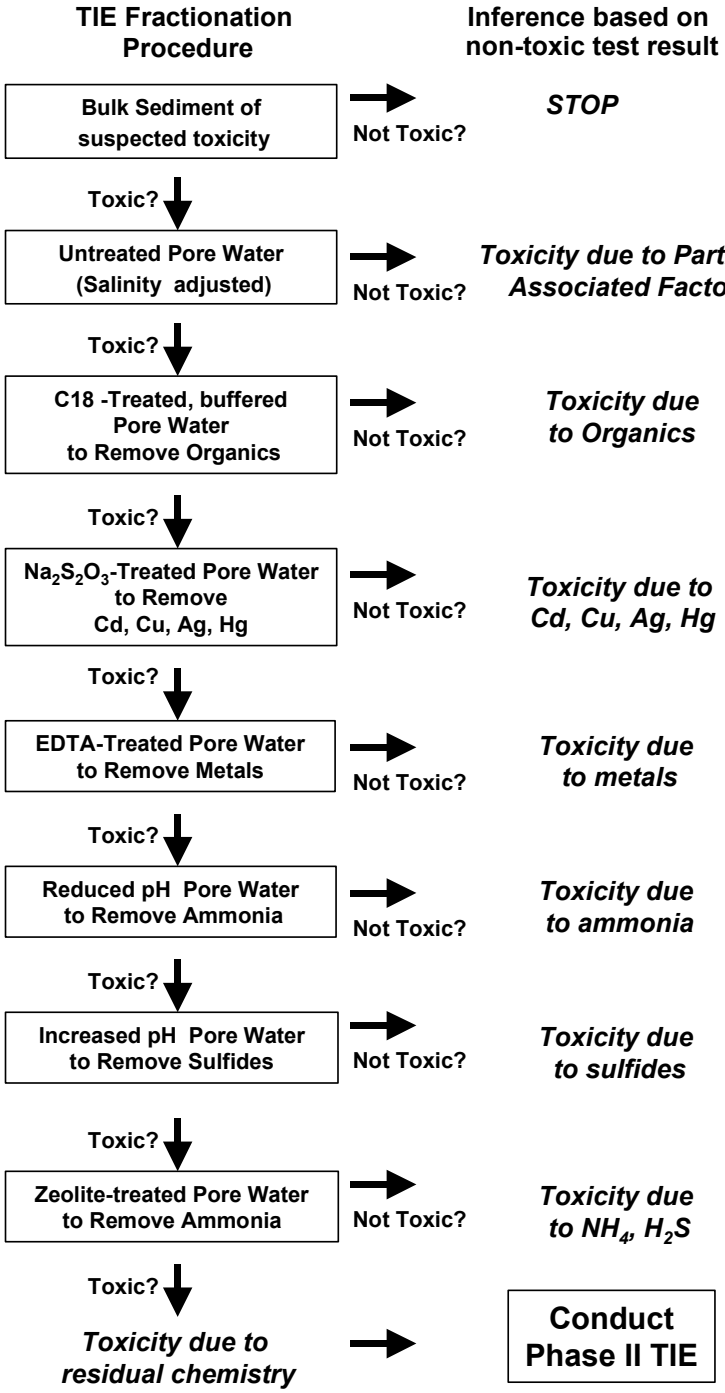

Table 2-1. Results from silver spiking study[a].

Sample	Silver (mg/Kg)	TOC (%)	AVS (μM/g)	Ag HQ SED/PW[2]	SEM[3] (μM/g)	NH4 (mg/L)	Toxicity
Bond Lake	200	0.22	<0.1	44.4/11.0	0.071	≤ 100[1]	-
Bond Lake	500	0.22	<0.1	111/41.0	0.071	≤ 100	* 33% less Growth

[a] data from Call et al. 1999

[1] Non-toxic in control sediment

[2] benchmarks of 4.5 ug/g and 3.1 ug/L used for sediment and porewater, respectively.

[3] SEM concentration excludes silver.

Table 2-2. Characteristics of Recommended Sites for the Indian Head TIE Demonstration.

SAIC TIE Sta.	Site Sample ID	Silver (g/Kg)	TOC[1] (%)	AVS (μM/g)	Ag HQ[2] Ag/2 (μM/g)[3]	Cationic Metals (μM/g)	NH4 (mg/L)	Bulk Sed. Toxicity	Characteristics
1	**S39SD04-a**	308	0.14	0.04	68 1.4	1.5 0.5[a]	NM	NM	High Ag
2	**S39SD04-b**								Field Rep.
3	**S39SD03**	66.4	0.14	0.02	15 0.3	3.9 1.9[a]	NM	NM	High Ag; Mixed metals
4	**S39SD03b**								Field Rep
5	**41DP04**	4.5	NM	NM	1.0 0.02	3.8	NM	NM	TPH; Mixed metals; Low Ag
6	**41DP05**	7.8	NM	NM	1.7 0.04	4.2	NM	NM	TPH; Mixed metals: Low Ag
7	**41DP07**	6.3	NM	NM	1.4 0.03	4.6	NM	NM	Mixed metals; Low Ag
8	**41DP09**	8.7	NM	NM	1.9 0.04	5.6	NM	NM	Mixed metals; Low Ag
9	**42SS6**	99	NM	NM (Low Fe)	22 0.5	3.5	NM	NM	High Ag; Mixed metals
10	**S42SD01/**	16.9	3.4	0.08	3.8/ 0.08	6.5 4.8[a]	NM	NM	Mixed metals
11	**S42SD026**	10.1	0.85	NM	2.2/ 0.04	2.1	3.6	*	Mod. Tox. Mixed metals
12	**S42SD014a** **S42SD014b**	75 88.7	1.37 1.3	NM	15.6-18.7/ 0.4		10.5	**	High Ag; High tox. Ammonia

SAIC TIE Sta.	Site Sample ID	Silver (g/Kg)	TOC[1] (%)	AVS (µM/g)	Ag HQ[2] Ag/2 (µM/g)[3]	Cationic Metals (µM/g)	NH4 (mg/L)	Bulk Sed. Toxicity	Characteristics
13	**S42SD008**	3.7 5.5	0.90	NM (Low Fe)	1.2/ 0.02	0.8-1.2	5.9	**	High tox. Ammonia Low metals
14	**S42SD0011**	4.5	0.82	NM	1.7/ 0.03	1.8	5.3	**	High tox. Low metals
15	**39SD08**	1.7	3.8	NM	0.37/ 0.07	0.7	NM	NM	Nitro-cellulose Other explosive derivatives

1 Toxicity of silver has been demonstrated to be reduced in proportion with dissolved organic carbon (Karen, et al. 1999; Bury et al. 1999). A similar correlation can be expected with TOC.

2 HQ = Hazard Quotient (the quotient of silver in mg/Kg divided by the Upper Effect Threshold reported for "Hyallela" tested in sediments contaminated with silver; lowest of reported values).

3 Ag/2, expressed in µM/g in order to estimate concentrations in excess of AVS (silver readily binds with sulfides to form insoluble silver sulfide which is not generally a source of toxicity; Berry et al. 1999). Note that molar silver concentrations greatly exceed AVS concentrations in the three samples where AVS was measured, indicating that most of the silver present may be bioavailable.

NM= Not Measured

* "Hyallela" Survival < statistically less than control

** "Hyallela" Survival < statistically less than control and 20% of control

[a] Measured Simultaneously Extracted Metals (SEM). Sum of cationic metals (Cu, Cd, Pb, Ni, Zn) reported here (top value) because data were available for most samples. Four measured SEM values ranged from 33-75% of summed cationic metals.

Table 2-3. Recommended sites for the Indian Head TIE Demonstration and rationale for selection.

TIE Station	Rationale for Selection
1	Site with the highest silver concentration (308 mg/Kg) from all of the RI Indian Head data. This value is 63 times the Upper Effect Threshold (UET HQ=63). TOC was very low (0.14%), increasing the potential for toxicity. SEM at this site was low, but positive (1.5 μM/g).
2	Serves as an additional sample for the Station 1 site because of the uncertainty and variability in silver and other metal concentrations surrounding this apparent silver hot spot. It is important to gain a better understanding of the spatial representation of this sample. See also Station 3 below.
3	Silver concentrations were high (15 times PEL), but four times lower than the proximate Station 1 (within a few meters) listed above. TOC was very low and equal to Site 1(0.14%). Similarly, SEM at this site was low, but positive (1.85 μM/g). Ni and Pb measurements exceeded the Probable Effect Level (PEL).
4	Again, an additional sample next to Station 3 is recommended because of the uncertainty and variability in silver and other metal concentrations surrounding this station. It is important to gain a better understanding of the spatial representation of this sample. See also Station 1 above.
5	Represents potentially different contaminant sources with the highest measured values of Total Petroleum Hydrocarbons (TPH = 215 mg/Kg). Location is adjacent to former transformer storage facility. Low silver (HQ=1), occurs at this site which is otherwise characterized with a moderate molar concentration of metals (3.8 μM/g).
6	Characteristics similar to Station 5, above, with TPH = 119 mg/Kg, but with slightly higher silver (HQ=1.7) and cationic metals (4.2 μM/g).
7	Subtidal station in Mattawoman Creek approximately 100 feet from shore locations of Stations 5 and 6 but with 50 mg/Kg TPH. Moderate concentrations of divalent cationic metals (4.6 μM/g). The silver HQ was 1.4. Cadmium was at the PEL level, Zn was measured at 3.2 μM/g (0.6 times PEL).
8	Mattawoman Creek station, approximately 100 feet from the easternmost limits of Site 41 and with chemical characteristics similar to Site 7. Divalent cationic metals were relatively elevated (5.6 μM/g). Silver HQ=1.8. Cadmium was at the PEL level, Zn was measured at 3.9 μM/g (0.8 times PEL) .
9	Site with highest measured silver of the Site 42 Landfill stations. Data do not include TOC, but iron values are an order of magnitude lower than other Site 42 samples. Cadmium was at the PEL level, but other metals were lower than at proximate stations.
10	Highest molar concentrations of divalent metals of the Site 42 stations. Silver HQ= 3.8 (0.08 μM/g). Zn was measured at 4.2 μM/g (0.9 times PEL). TOC was higher (3.4%) than other stations at Site 42.
11	Mouth of the stream locations; silver concentration (HQ= 2.1-4.) similar to Station 10, but with lower TOC (1.0%) and low cationic metals (1.5 μM/g).
12	Highly toxic to *Hyallela*. Total ammonia values were also higher than in any other tested sample (10 mg/L). Silver values were almost as high as in Station 9, but other metals were not measured. TOC was 1.4 %. One of few stations where phenolics were measured, and some were above UET and AET values.
13	Highly toxic to *Hyallela*, with low silver (HQ = 1.2) and other metal concentrations (0.8-1.2 μM/g). High toxicity to Hyallela correlated with relatively high total ammonia concentrations (5.9 mg/L). Low individual metal concentrations (highest was 0.3 μM/g).
14	Highly toxic to *Hyallela*, and similar to Station 13, but with slightly higher silver (HQ = 1.7) and other metal concentrations (1.8 μM/g).
15	Site to investigate the potential explosive-related toxicity. The site represents the highest concentration of nitrocellulose (1,580,000 μg/Kg) measured for Site 39/41 and Site 42.

Table 3-1. Summary of the bulk sediment toxicity test procedures with *Hyallela azteca* [a]

Test Duration	10 days
Number of Organisms per Chamber	20
Number of Replicates per Treatment	8
Test Chambers	800 mL glass jars
Test Temperature	23 ^{o}C
Salinity	0 ppt
Photoperiod	7-14 days
Volume of Sediment	175 mL
Volume of Overlying Water	625 mL
Type of Water	clean freshwater
Bay Feeding/Chamber	YCT
Endpoint	survival
Acceptance Criteria	85% survival in control

a EPA, 1998. Methods for Measuring the Toxicity and Bioaccumulation of Sediment-Associated Contaminants with Freshwater Invertebrates. Second Ed. EPA 600/R-98/XXX. EPA Office of Research and Development, Duluth, MN.

Table 3-2. Summary of TIE Tiers/Characterizations and study treatments.

	Base-line	C_{18}	EDTA	$Na_2S_2O_3$	PH ~ 6	PH ~ 7	Zeolite
Sediment PW 1	X	X	X	X	X	X	X
Sediment PW 2	X	X	X	X	X	X	X
Sediment PW 3	X	X	X	X	X	X	X
Sediment PW 4	X	X	X	X	X	X	X
Sediment PW 5	X	X	X	X	X	X	X
Sediment PW 6	X	X	X	X	X	X	X
Sediment PW 7	X	X	X	X	X	X	X
Sediment PW 8	X	X	X	X	X	X	X
Sediment PW 9	X	X	X	X	X	X	X
Sediment PW 10	X	X	X	X	X	X	X
Sediment PW Control	X	X	X	X	X	X	X
Spiked FW		A	a	A	a	a	a
Performance Control	X	Xb	Xc	Xd	Xe	Xf	Xg

PW = pore water, Ref. = reference station, SW = seawater, FW = freshwater, performance control = freshwater or seawater.
a = spiked control will be manipulated and analyzed for chemistry only, toxicity tests will not be performed;
b = C_{18} control
c = EDTA performance control; d = $Na_2S_2O_3$ performance control; e = low pH performance control; f = high pH performance control; g = zeolite performance control

Table 3-3. Summary of test conditions for acute water-only toxicity tests with the freshwater fish, *Pimepheles promelas*[a] and the freshwater amphipod, *Hyallela azteca*[b]

	P. promelas	*H. azteca*
Test type	Static non-renewal	Static non-renewal
Test Duration	72 hr	48 hr
Number of Replicates per Treatment	3	3
Number of Organisms per Chamber	5	5
Test Chambers	25 mL vial	25 mL vial
Test Temperature	25°C	23 °C
Test concentrations	4 (10, 25, 50, 100%)	4 (10, 25, 50, 100%)
Salinity	0 ppt	0 ppt
Photoperiod	16:8	16:8
Age/Size of Test Organisms	24 hr. old	7-14 days
Volume of Overlying Water	20 mL	20 mL
Type of Water	clean freshwater	clean freshwater
Bay Feeding/Chamber none	none	
Endpoint	survival	survival
Physical measurements[1]	Dissolved oxygen, pH ammonia, temperature	Dissolved oxygen, pH ammonia, temperature
Acceptance Criteria	80% survival in control	85% survival in control

a. U.S. EPA 1991. Methods for aquatic toxicity identification evaluations: Phase I toxicity characterization procedures. EPA-600/3-88-034. Environmental Research Laboratory, Duluth, MN.

b. U.S. EPA 1998. Methods for Measuring the Toxicity and Bioaccumulation of Sediment-Associated Contaminants with Freshwater Invertebrates. Second Ed. EPA 600/R-98/XXX. EPA Office of Research and Development, Duluth, MN.

1- measured for each treatment prior to addition of test organisms, and as required to monitor stability

Table 3-4. Contaminants measured in sediments and pore waters for the Indian Head TIE demonstration program.

Analytes for Sediment Analyses	*Method*	*Description*	*Unit*	*MDL*	*Laboratory RL*
INORGANICS					
TOC	SW9060	Combustion	mg/kg	547	6000
METALS					
Aluminum	SW3050B/6010B	ICP	mg/kg	3.7	20.0
Antimony	SW3050B/6010B	ICP - Trace	mg/kg	0.22	0.60
Arsenic	SW3050B/6010B	ICP - Trace	mg/kg	0.093	1.0
Cadmium	SW3050B/6010B	ICP - Trace	mg/kg	0.022	0.50
Chromium	SW3050B/6010B	ICP - Trace	mg/kg	0.091	1.0
Copper	SW3050B/6010B	ICP - Trace	mg/kg	0.17	1.0
Lead	SW3050B/6010B	ICP - Trace	mg/kg	0.093	0.30
Iron	SW3050B/6010B	ICP	mg/kg	3.1	10.0
Nickel	SW3050B/6010B	ICP - Trace	mg/kg	0.25	1.0
Silver	SW3050B/6010B	ICP - Trace	mg/kg	0.28	1.0
Zinc	SW3050B/6010B	ICP	mg/kg	0.79	2.0
Mercury	SW7471A	Cold Vapor	mg/kg	0.027	0.10
PESTICIDES					
Aldrin	SW3540C/8081A	GC/ECD	ug/kg	0.52	1.7
a-Chlordane	SW3540C/8081A	GC/ECD	ug/kg	0.70	1.7
g-Chlordane	SW3540C/8081A	GC/ECD	ug/kg	0.35	1.7
4,4'-DDD	SW3540C/8081A	GC/ECD	ug/kg	0.42	3.3
4,4'-DDE	SW3540C/8081A	GC/ECD	ug/kg	0.40	3.3
4,4'-DDT	SW3540C/8081A	GC/ECD	ug/kg	0.66	3.3
Dieldrin	SW3540C/8081A	GC/ECD	ug/kg	0.43	3.3
Endosulfan I	SW3540C/8081A	GC/ECD	ug/kg	0.72	1.7
Endosulfan II	SW3540C/8081A	GC/ECD	ug/kg	0.36	3.3
Endrin aldehyde	SW3540C/8081A	GC/ECD	ug/kg	0.94	3.3
Heptachlor	SW3540C/8081A	GC/ECD	ug/kg	0.60	1.7
Heptachlor epoxide	SW3540C/8081A	GC/ECD	ug/kg	0.81	1.7
Hexachlorobenzene	SW3540C/8081A	GC/ECD	ug/kg	0.84	3.3
Alpha-Hexacyclochlorohexane	SW3540C/8081A	GC/ECD	ug/kg	TBD	1.7
Beta-Hexacyclochlorohexane	SW3540C/8081A	GC/ECD	ug/kg	TBD	1.7
Mirex	SW3540C/8081A	GC/ECD	ug/kg	TBD	3.3
Toxaphene	SW3540C/8081A	GC/ECD	ug/kg	14	170
PCB CONGENERS					
2,4'-dichlorobiphenyl (BZ # 8)	SW3540C/8082	GC/ECD	ug/kg	0.10	1.0
2,2',5-trichlorobiphenyl (BZ # 18)	SW3540C/8082	GC/ECD	ug/kg	0.10	1.0
2,4,4'-trichlorobiphenyl (BZ # 28)	SW3540C/8082	GC/ECD	ug/kg	0.037	1.0
2,2',3,5'-tetrachlorobiphenyl (BZ # 44)	SW3540C/8082	GC/ECD	ug/kg	0.11	1.0
2,2',5,5'-tetrachlorobiphenyl (BZ # 52)	SW3540C/8082	GC/ECD	ug/kg	0.10	1.0
2,3',4,4'-tetrachlorobiphenyl (BZ # 66)	SW3540C/8082	GC/ECD	ug/kg	0.056	1.0
3,3',4,4'-tetrachlorobiphenyl (BZ # 77)	SW3540C/8082	GC/ECD	ug/kg	0.082	1.0
2,2',4,5,5'-pentachlorobiphenyl (BZ # 101)	SW3540C/8082	GC/ECD	ug/kg	0.058	1.0
2,3,3',4,4'-pentachlorobiphenyl (BZ # 105)	SW3540C/8082	GC/ECD	ug/kg	0.18	1.0
2,3',4,4',5-pentachlorobiphenyl (BZ # 118)	SW3540C/8082	GC/ECD	ug/kg	0.069	1.0
3,3',4,4',5-pentachlorobiphenyl (BZ # 126)	SW3540C/8082	GC/ECD	ug/kg	0.049	1.0
2,2',3,3',4,4'-hexachlorobiphenyl (BZ # 128)	SW3540C/8082	GC/ECD	ug/kg	0.048	1.0
2,2',3,4,4',5'-hexachlorobiphenyl (BZ # 138)	SW3540C/8082	GC/ECD	ug/kg	0.043	1.0
2,2',4,4',5,5'-hexachlorobiphenyl (BZ # 153)	SW3540C/8082	GC/ECD	ug/kg	0.037	1.0
2,2',3,3',4,4',5-heptachlorobiphenyl (BZ # 170)	SW3540C/8082	GC/ECD	ug/kg	0.071	1.0
2,2',3,4,4',5,5'-heptachlorobiphenyl (BZ # 180)	SW3540C/8082	GC/ECD	ug/kg	0.087	1.0

2,2',3,4',5,5',6-heptachlorobiphenyl (BZ # 187)	SW3540C/8082	GC/ECD	ug/kg	0.060	1.0
2,2',3,3',4,4',5,6-octachlorobiphenyl (BZ # 195)	SW3540C/8082	GC/ECD	ug/kg	0.087	1.0
2,2',3,3',4,4',5,5',6-nonachlorobiphenyl (BZ # 206)	SW3540C/8082	GC/ECD	ug/kg	0.13	1.0
2,2',3,3',4,4',5,5',6,6'-decachlorobiphenyl (BZ # 209)	SW3540C/8082	GC/ECD	ug/kg	0.16	1.0
SVOCs					
Acenaphthene	SW3540C/8270C -Low	GC/MS	ug/kg	0.6	2
Acenaphthylene	SW3540C/8270C -Low	GC/MS	ug/kg	0.67	2
Anthracene	SW3540C/8270C -Low	GC/MS	ug/kg	0.67	2
Benzo[a]anthracene	SW3540C/8270C -Low	GC/MS	ug/kg	0.76	2
Benzo[b]fluoranthene	SW3540C/8270C -Low	GC/MS	ug/kg	1.5	2
Benzo[k]fluoranthene	SW3540C/8270C -Low	GC/MS	ug/kg	0.85	2
Benzo[a]pyrene	SW3540C/8270C -Low	GC/MS	ug/kg	0.86	2
Benzo(e)pyrene	SW3540C/8270C -Low	GC/MS	ug/kg	1.11	2
Benzo[ghi]perylene	SW3540C/8270C -Low	GC/MS	ug/kg	1.71	2
Biphenyl	SW3540C/8270C -Low	GC/MS	ug/kg	0.9	2
Chrysene	SW3540C/8270C -Low	GC/MS	ug/kg	0.6	2
Dibenzo[a,h]anthracene	SW3540C/8270C -Low	GC/MS	ug/kg	1.86	2
Fluoranthene	SW3540C/8270C -Low	GC/MS	ug/kg	0.46	2
Fluorene	SW3540C/8270C -Low	GC/MS	ug/kg	0.42	2
Indeno[1,2,3-cd]pyrene	SW3540C/8270C -Low	GC/MS	ug/kg	1.78	2
2-Methylnaphthalene	SW3540C/8270C -Low	GC/MS	ug/kg	0.4	2
2,6-Dimethylnaphthalene	SW3540C/8270C -Low	GC/MS	ug/kg	0.99	2
2,3,5-Trimethylnaphthalene	SW3540C/8270C -Low	GC/MS	ug/kg	1.14	2
Naphthalene	SW3540C/8270C -Low	GC/MS	ug/kg	0.22	2
1-Methylphenanthrene	SW3540C/8270C -Low	GC/MS	ug/kg	0.42	2
Phenanthrene	SW3540C/8270C -Low	GC/MS	ug/kg	0.47	2
Perylene	SW3540C/8270C -Low	GC/MS	ug/kg	1.13	2
Pyrene	SW3540C/8270C -Low	GC/MS	ug/kg	0.42	2
1-Methylnaphthalene	SW3540C/8270C -Low	GC/MS	ug/kg	0.61	2
EXPLOSIVES					
HMX	SW8330	HPLC	ug/kg	190	500
RDX	SW8330	HPLC	ug/kg	180	500
135TNB	SW8330	HPLC	ug/kg	83	250
13DNB	SW8330	HPLC	ug/kg	73	250
NB	SW8330	HPLC	ug/kg	110	250
TETRYL	SW8330	HPLC	ug/kg	240	750
246TNT	SW8330	HPLC	ug/kg	180	500
2amDNT	SW8330	HPLC	ug/kg	140	500
4amDNT	SW8330	HPLC	ug/kg	220	500
24DNT	SW8330	HPLC	ug/kg	86	250
26DNT	SW8330	HPLC	ug/kg	200	500
2NT	SW8330	HPLC	ug/kg	150	500
3NT	SW8330	HPLC	ug/kg	230	500
4NT	SW8330	HPLC	ug/kg	120	500
Pentaerythritol tetranitrate (PETN)	SW8330	HPLC	ug/kg	660	2000
Nitroglycerin	SW8330	HPLC	ug/kg	240	1000
SEM					
Cadmium	US EPA 1992/6010B	ICP/AES	umol/g	0.002	0.1
Copper	US EPA 1992/6010B	ICP/AES	umol/g	0.005	0.1
Lead	US EPA 1992/6010B	ICP/AES	umol/g	0.015	0.1
Nickel	US EPA 1992/6010B	ICP/AES	umol/g	0.045	0.1
Silver	US EPA 1992/6010B	ICP/AES	umol/g	TBD	TBD
Zinc	US EPA 1992/6010B	ICP/AES	umol/g	0.030	0.1
Acid Volatile Sulfides	US EPA 1992/6010B	ICP/AES	umol/g	0.075	0.1

Analytes for Pore Water Analyses-Fresh					
Cadmium	6020	ICP/MS	µg/L	0.19	2.0
Copper	6020	ICP/MS	µg/L	1.4	2.0
Lead	6020	ICP/MS	µg/L	0.22	2.0
Nickel	6020	ICP/MS	µg/L	1.1	2.0
Silver	6020	ICP/MS	µg/L	0.15	2.0
Zinc	6020	ICP/MS	µg/L	4.0	10.0
Arsenic	6020	ICP/MS	µg/L	0.24	2.0
Iron	6020	ICP/MS	µg/L	85	200
Aluminum	6020	ICP/MS	µg/L	17	20
TOC	SW9060	Combustion	mg/L	0.19	1.0
Sulfide	SW9034	Titration	mg/L	0.25	1.0